Field Assessment Techniques for Bank Erosion Modeling

First Interim Report

Prepared for

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It is often difficult to identify processes, mechanisms and causes of river bank erosion correctly in the field. An assessment sheet has been developed as an aid to field reconnaissance for this purpose. Because bank erosion problems are closely linked to broader Sedimentation issues and sediment impacts, the sheets encompass information on all aspects of Sedimentation assessment. The data collected are sufficient for bank stability models to be applied, and also could form the basis for qualitative analysis of channel stability problems as a precursor to the design of a stable geometry.

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APPENDICES

1. SCIENTIFIC WORK DONE

1.1 Logistics

The project has involved a concentrated and extended effort by the principal investigator, Colin Thorne, working personally on this project over a four month period.

In August the PI met the engineer in charge of the relevant work unit at the Waterways Experiment Station (Bradley Comes) at the San Diego meeting of the American Society of Civil Engineers. The PI presented a paper on bank stability response to channel grade control (Biedenharn et al., 1990) and Mr Comes presented a paper based on the first version of the Bank Erosion Assessment Guidelines (Thorne and Abt, 1989; Comes, 1990). They discussed the formulation and rationale behind the sheets and the comments and criticisms obtained from Professor Joseph Hagerty under a separate work order. Plans were made and dates set for field testing and evaluation of the sheets and guidelines after their revision in the light of the comments to date. It was planned to undertake fieldwork in early October.

However, in late August Mr Comes resigned his position in the Hydraulics Laboratory and moved to a new post in the Information Technology Laboratory. His supervisor, Dr Tony Thomas, took over direct control of the Bank Erosion Work Unit.

During September the Principal Investigator worked at the University of Nottingham to completely revise the Bank Erosion Assessment Sheets and their Guidelines on the basis of comments and criticisms of the earlier version, and experience of their use by the Principal Investigator and other scientists and engineers at WES during June 1990.

In early October further discussions took place by telephone and FAX between the PI and Dr Thomas regarding the scope, applicability and type information recorded on the sheets. With his wider perspective of river mechanics and stable channel design, Dr Thomas wished to see the sheets further modified and broadened to include more quantitative data and to cover all aspects of river sedimentation and sediment impacts, rather than concentrating solely on the banks. This approach is more demanding of the sheets and guidelines, but it has the potential to make them much more valuable as a tool in collecting and assembling the data required for semi-quantitative and quantitative engineering-geomorphic analyses of rivers. The PI agreed whole heartedly with the thinking behind Dr Thomas's proposed development of the sheets.

By mid-October the sheets had been broadened to include greater consideration of the sedimentary processes and forms of the whole channel, and allow for the recording of quantitative measurements of channel size, geometry and sediment characteristics. The revised sheets may be found in Appendix A. To differentiate them from the earlier version and reflect their broadened scope, they have been re-named 'Sedimentation Analysis Sheets'.

The guidelines for use of the sheets had also to be heavily revised and broadened and this too was complete by mid-October. Revised guidelines may be found in Appendix B.

In a previous study, discussion had taken place between the PI and Mr Comes regarding the equipment needed to facilitate the collection of quantitative data during field reconnaissance trips. A field satchel or backpack was envisaged, containing everything needed by an engineer or geomorphologist charged with conducting a reconnaissance trip to a stream or river. Prior to his resignation Mr Comes acted on this idea by ordering the equipment required. Dr Thomas and Mr Robert McCarley at WES reconsidered the type of field equipment needed to make the field measurements involved in the new approach and found that this was well covered by the equipment already purchased and assembled at WES. A list of the equipment included in a standard field backpack may be found in Appendix B.

On October 15 the PI traveled to Vicksburg to meet with Dr Thomas, undertake field evaluation of the revised sheets, guidelines and field equipment, and plan the remainder of the project.

With Mr Comes's resignation, it was possible at this time to undertake the fieldwork around the country planned in the original proposal. Instead, by agreement with Dr Thomas, this major fieldtrip was postponed until the Spring of 1991, by which time a new leader for the Bank Erosion Work Unit will have been appointed. However, in order to keep the project moving forward, the opportunity was taken to test the sheets and guidelines locally by incorporating their use into a short course being run at WES at the time. This course, 'Sedimentation Investigations of Rivers and Reservoirs' included a field reconnaissance trip to a local water course and involved 18 engineers from several US Army Corps of Engineers Districts. These individuals had a wide range of background and degrees past experience in sedimentation engineering and field work. Hence, the group represented just the types of people required to test the sheets and guidelines as set out in the original proposal.

A one hour introductory lecture on sediment impact assessment was given by the PI on the morning of October 18 and the field reconnaissance trip was undertaken that afternoon to Clear Creek, Bovina, Mississippi. The results of the trip were discussed in the field that evening. A wrap-up session was held on the morning of October 19, to synthesize the main findings and allow feed back from the short course participants to the PI and Dr Thomas.

The results, comments, criticisms and recommendations are presented and discussed in the next 4 sections.

1.2 Bank Erosion Assessment Sheet Evaluation

The preliminary assessment sheets developed by Thorne and Abt (1989) were evaluated in the light of critical comment from project reviewers at the University of Louisville and post-project input from engineers and scientists at the US Army Engineer Waterways Experiment Station. The changes made are detailed below.

The Title of the sheets has been changed to 'Sedimentation Analysis Sheets', to reflect their increased scope. The heading box use a defined reach in place of a location to delineate the study area. **Parts 1 and 2** are essentially unchanged from the original version.

Part 3 has been heavily re-worked. It was realized that elements of observation were mixed with elements of interpretation in the old sheets. Also, the person completing the sheets was predicting future trends in river development while at the same time noting the present status. This led to some confusion. In the new version, the engineer is asked to record what he or she observes without at this stage making a prediction about the future. Questions concerning controls in the bed of the channel have been moved from this part to part 5 of the sheet (Channel Description). A section has been added on overbank deposits, and quantitative data on any levees present is now requested.

Part 4 has been similarly re-worked. It is more observational and excludes prediction about future trends. Questions about lateral channel controls have been moved to Part 5 and quantitative data defining the planform is now requested.

Part 5 now contains all questions pertaining to the form and controls of the channel. Measured dimensions are requested both for the flow on the day of observation and the channel full condition. The flow regime is defined and information on bed and bank controls recorded.

Part 6 is an entirely new part dealing in detail with the description of the bed sediments. The bed material is described by its type in the Wentworth Scale. The presence of an armor layer and the depth of loose sediment are noted and quantitative data on the size distributions of surface and substrate sediments are requested. The presence and types of sedimentary features such as bars and islands is dealt with, again with quantitative data on surface and substrate sediment size distributions for bar sediments.

Parts 7 to 11 now deal with the left bank. The Parts are equivalent to Parts 6 to 10 in the old sheets. In the text below, the old part number appears in brackets behind its new equivalent. In **part 7** (6), a section has been added to note the status of the bank in relation to bank protection structures. Also, measured values for bank height and angle replace the ranges requested in the old sheets. Similarly, actual layer thicknesses in feet replace the terms "thick" and "thin" in the old sheets. Finally, tension cracks are known to be very damaging to bank stability. There presence and extent is noted in the new sheets.

Parts 8 (7) **to 10** (9) are unchanged in the new sheets, but **Part 11** (10) has been extensively re-worked. The requirement to predict sedimentation trends has been removed. Often, berms are found only behind point bars in bendways. This fact can now be noted in anew section on Berm Location. Berm materials are now defined both by their Wentworth Scale classification and quantitatively through their size distribution. Berm vegetation is still described in detail, but a section on vegetation spacing has been added for consistency with Part 8 (7).

Parts 12 (11) **to 16** (15) repeat the questions for the right bank of the channel.

1.3 Bank Erosion Assessment Sheet Testing

1.3.1 Fieldwork

Field testing of the Sedimentation Analysis Sheets was undertaken on Clear Creek, Mississippi with a group of 18 engineers from a wide variety of Corps Districts. The aim was to identify areas of weakness or ambiguity . Particular attention was paid to the complexity of the sheets and the potential for different groups working on the same reach of channel to supply different answers to the questions.

The class was divided into 6 groups of 3 people each. Because of time limitations (only 3 hours were available for the whole exercise) and the relative inexperience of the engineers in stream reconnaissance, it was not possible for each group to complete all three Sediment Analysis Sheets. Instead, the 6 groups were arranged into 2 teams. Each team had each group fill out a single sheet. That is, Team A had its first group fill out the Valley and Channel Survey, its second group fill out the Left Bank Survey and its third group fill out the Right Bank Survey. Team B was arranged similarly. At the end of the reconnaissance the groups pooled their results with the rest of their team. Consequently, 2 sets of completed sheets were obtained. The completed sheets are shown in Appendix C.

1.3.2 Discussion of Results

The results of the field testing of the sheets are included in Appendix D. These results are encouraging. There is general agreement between the two teams on most of the features of the valley, channel, bed and banks. In depth analysis of the results, together with the several pages of notes and detailed comments submitted by the short course students will take some time. By the Spring of 1991, the PI will have fully considered the results and further enhanced the sedimentation sheets accordingly. They will then be ready for the final development phase, field testing in a variety of rivers of different sizes, with different sedimentary environments and in different physiographic regions.

1.4 Bank Erosion Assessment Sheet Guideline Evaluation

The preliminary guidelines for application of the bank erosion assessment sheets developed by Thorne and Abt (1989) were evaluated in the light of critical comment from project reviewers at the University of Louisville and post-project input from engineers and scientists at the US Army Engineer Waterways Experiment Station. A start was made on incorporating photographs into the guidelines, but this was suspended when the scope of the sheets was increased from bank assessment to sedimentation analysis. Significant improvements were made and the guidelines for completion of the bank assessment sheets were rewritten in line with the modified sedimentation sheets. It is proposed to return to the incorporation of photographs into the guidelines in the Spring of 1991, once the scope and general form of the sheets has been finally decided.

1.5 Bank Erosion Assessment Sheet Guideline Testing

Field testing of the modified sedimentation sheet guidelines was undertaken on Clear Creek by the Sedimentation short course students. Particular attention was paid to ease of comprehension and clarity of statement in the guidelines.

The Corps engineers then briefed the PI and WES scientists regarding the strengths and weaknesses of the guidelines as they perceived them, and suggest changes and improvements as necessary. The intention is to us e these comments to help produce a set of guidelines which is genuinely usable by non-specialist personnel, this is a fundamental aspect of the project.

1.6 Bank Erosion Assessment Sheet and Guideline Development

Work is now in hand to incorporate the experience gained and comments made in the October testing of the sheets and guidelines into an improved set of sheets and guidelines. These comments are listed in Appendix D. Over the winter steps will be taken to further develop the sheets and guidelines to produce an assessment system suitable for routine use nationwide by non-expert personnel.

2. RESEARCH PLANS

In the final phase, Phase 3, it is intended to complete development the sheets and guidelines on the basis of the direct field experience in a variety of physiographic environments. This part of the project will involve incorporating improvements, deleting extraneous sections, and optimizing the gathering of information, so that the resulting sheets and guidelines are both comprehensive and accurate, while being manageable and unambiguous. Phase 3 will be undertaken during May and June 1991. The latest version of the bank erosion assessment sheets will be field tested by the Principal Investigator together with the new engineer in charge of the bank erosion work unit from US Army Engineer Waterways Experiment Station, using field sites on a variety of rivers within the contiguous United States. It is planned to visit between 3 and 6 separate locations, working at several specific sites at each location. These locations and sites will be selected to include a wide range of river environments, in terms of the physiographic regions drained by the rivers, the size and morphology of the channels, the nature of the bed and bank materials, and, most particularly, the range of causes, processes and mechanisms involved in bank retreat. It is expected that, where appropriate, specialist and non-specialist engineers and scientists from local District Offices of the Corps of Engineers will accompany the PI and WES personnel into the field to assist in the on-site testing of the assessment sheets. The local knowledge so gained will be vital to in-depth testing of the sheets. The precise details of the locations, sites, participants and logistics is being worked out with WES staff.

The anticipated products are:

1. Tested and verified Bank Erosion Assessment Sheets to be used as an aid to field identification of:

a) the state of vertical and lateral channel stability;
b) the relation of local bank retreat to channel instability;
c) the engineering and morphological characteristics of the banks;
d) the dominant erosive forces and processes;
e) the state of bank stability and the major failure mechanisms;
f) the severity and extent of bank erosion in the reach; and
g) the input parameters necessary for modeling bank retreat.

2. Documentation providing clear and detailed guidance on the use of the bank erosion assessment sheets for use by personnel who are not experts on bank erosion.

3. ADMINISTRATIVE ACTIONS

There have been no significant administrative actions during this period.

4. REFERENCES

Biedenharn, D.S., Little, C.D., and Thorne, C.R. (1990) "Effects of low drop grade control structure on bed and bank stability" in, Hydraulic Engineering, H.H. Chang and J.C. Hill (Eds.), Proceedings of the National Conference on Hydraulic Engineering, ASCE, San Diego, August 1990, 826-831.

Comes, B.M. (1990) "Identification techniques for bank erosion and failure processes" in, Hydraulic Engineering, H.H. Chang and J.C. Hill (Eds.), Proceedings of the National Conference on Hydraulic Engineering, ASCE, San Diego, August 1990, 193-197.

Thorne, C.R. and Abt, S.R. (1989) "Bank Erosion Modeling and Assessment Techniques" Final Report to the US Army Engineers Waterways Experiment Station, under contract number DACW39-87-D-0031, Colorado State University, Ft Collins, Co., November 1989, 4 Parts.

APPENDIX A Revised Bank Erosion Assessment Sheets and Bank Erosion Sheet Guide-lines

SEDIMENTATION ANALYSIS SHEETS

and

GUIDELINES FOR THE USE OF SEDIMENTATION ANALYSIS SHEETS IN THE FIELD

Prepared for

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* Note

page numbers refer to pages as they appear in the original document, not their numbers in this Appendix.

SEDIMENTATION ANALYSIS SHEET
Developed by Colin R. Thorne
for the US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

RIVER | SITE | REACH From | To
SHEET COMPLETED BY | DATE | TIME: START | TIME: FINISH

SECTION 1 - VALLEY AND CHANNEL SURVEY

PART 1: AREA AROUND RIVER VALLEY

Terrain: Mountains, Uplands, Hills, Plains, Lowlands

Geology: Bed rock, Moraine, Glacio/Fluvial, Fluvial, Lacustrine, Wind blown (loess)

Rock Type: Cemented Clay, Shale, Limestone, Sandstone, Conglomerate, Granite

Land Use: Natural, Cultivated, Urban

Vegetation: None, Grass, Arable Crops, Shrubs, Forest

Forest Type: None, Deciduous, Coniferous, Mixed

PART 2: VALLEY SIDES

Height: < 20 feet, 20-50 feet, 50-100 feet, >100 feet

Side Slope Angle: < 30 degrees, 30-60 degrees, >60 degrees

Valley side Failures: None, Occasional, Frequent

Severity of Problems: Insignificant, Moderate, Serious

Failure Locations: None, Away from river, Along river (Undercut)

Failure Types: None, Shallow slide, Rotational slip, Slab-type, Piping, Flow failure

PART 3: VERTICAL RELATION OF CHANNEL TO VALLEY

Present status: Adjusted, Incised, Aggraded

Instability:Status: Insignificant, Moderate, Serious

Instability:extent: None, Local, General, Reach scale, System wide, Regional scale

Terraces: None, Indefinate, Fragmentary, Continuous, Number of terraces

Number of Terraces: Number above valley Floor

Overbank Deposits: None, Silt, Fine sand, Medium sand, Coarse sand, Gravel

Levees: None, Indefinate, Fragmentary, Continuous

Levee Type: Natural, Man-made

Levee Data: Height (f), Side Slope (o)

Levee Failures: None, Occasional, Frequent

PART 4: LATERAL RELATION OF CHANNEL TO VALLEY

Present Status: Adjusted, over wide, narrow

Instability:Status: Insignificant, Moderate, Serious

Instability:extent: None, Local, General, Reach scale, System wide, Regional scale

Planform: Straight, Sinuous, Irregular, Regular meanders, Irregular meanders, Tortuous meanders, Braided

Planform Data: Bend Radius, Meander belt width, Wavelength, Meander Sinuosity

Valley Floor Type: None, Indefinate, Fragmentary, Continuous

Valley Floor Data: < 1 river width, 1 - 5 river widths, > 5 river widths

Note:
width = channel top width

PART 5: CHANNEL DESCRIPTION

Dimensions: Ave. top bank width, Ave. channel depth, Ave. water width, Ave. water depth, Reach slope, Mean velocity, Manning's n value

Flow Type: None, Uniform/Tranquil, Uniform/Rapid, Pool+Riffle, Tumbling, Step-pool

Bed Controls: None, Occasional, Frequent, Confined, Number of controls

Control Types: None, Bedrock, Boulders, Gravel armor, Bridge aprons, Grade control structures

Width Controls: None, Occasional, Frequent, Confined, Number of controls

Control Types: None, Bedrock, Boulders, Gravel armor, Revetments, Bridge abutments, dykes or groynes

PART 7: BED SEDIMENT DESCRIPTION

Bed Material: Silt, Sand, Sand and gravel, gravel and cobbles, cobbles + boulders, boulders + bedrock, Bed rock

Bed Armour: None, Static-armour, Mobile-armour

Sediment Depth: Depth of loose Sediment in bed (ft)

Surface Size Data: D50 (mm), D84 (mm), sorting coefficient

Substrate Size Data: D50 (mm), D84 (mm), sorting coefficient

Bed Forms: Plane bed, Ripples, Dunes, Bed form height (ft)

Island or Bars: None, Occasional, Frequent

Bar Types: None, Pools and riffles, Alternate bars, Point bars, Mid-channel bars, Diagonal bars, Sand waves + dunes

Bar Surface data: D50 (mm), D84 (mm), sorting coef.

Bar Substrate data: D50 (mm), D84 (mm), sorting coef.

SECTION 2 - LEFT BANK SURVEY

PART 8: LEFT BANK CHARACTERISTICS

Type
- Noncohesive
- Cohesive
- Composite
- Layered
- Even Layers
- Thick+thin layers
- Number of layers

Protection Status
- Unprotected
- Hard points
- Revetments
- Dyke Fields

Bank Materials
- Silt/clay
- Sand/silt/clay
- Sand/silt
- Sand
- Sand/gravel
- Gravel
- Gravel/cobbles
- Cobbles
- Cobbles/boulders
- Boulders/bedrock

Mean Bank Height
- Average height (ft)

Mean Bank Slope
- Average angle (o)

Layer Thickness
- Material 1 (ft)
- Material 2 (ft)
- Material 3 (ft)
- Material 4 (ft)

Tension Cracks
- None
- Occasional
- Frequent

Crack Extent
- Proportion of bank height

Distribution and Description of Bank Materials in Bank Profile

Material Type 1
- Toe
- Mid-Bnak
- Upper Bank
- Whole Bank
- D50 (mm)
- sorting coefficient

Material Type 2
- Toe
- Mid-Bnak
- Upper Bank
- Whole Bank
- D50 (mm)
- sorting coefficient

Material Type 3
- Toe
- Mid-Bnak
- Upper Bank
- Whole Bank
- D50 (mm)
- sorting coefficient

Material Type 4
- Toe
- Mid-Bnak
- Upper Bank
- Whole Bank
- D50 (mm)
- sorting coef.

PART 9: LEFT BANK-FACE VEGETATION

Vegetation
- None
- Cleared
- Grass and flora
- Reeds and sedges
- Shrubs
- Saplings
- Trees

Tree Types
- None
- Alder
- Ash
- Beech
- Birch
- Cottonwood
- Elm
- Sweet gum
- Willow

Density
- None
- Sparce
- Medium
- Dense

Spacing
- Continuous
- Close
- Wide

Location
- Whole bank
- Bank top
- Mid-bank
- Bank toe

Diversity
- Mono-stand
- Mixed
- Climax-vegetation

Health
- Healthy
- Fair
- Poor
- Dead

Age
- Imature
- Mature
- Old

Height
- Short
- Medium
- Tall

Extent
- Wide
- Medium
- Narrow

PART 10: LEFT BANK EROSION PROCESSES

Status
- Intact
- Eroding
- Advancing

Severity
- Insignificant
- Mild
- Significant
- Serious
- Catastrophic

Extent
- Toe
- Lower bank
- Upper bank
- Whole bank

Estimated rate
- < 3ft/yr
- 3 - 10 ft/yr
- 10 - 25 ft/yr
- >25 ft/yr

Location
- General
- Outside Meander
- Inside Meander
- Opposite a bar
- Behind a bar
- Opposite a structure
- Adjacent to structure
- Dnstream of structure
- Upstream of structure
- Other

Processes
- Flow entrainment
- Piping
- Freeze/thaw
- Sheet erosion
- Rilling + gullying
- Wind waves
- Vessel Forces
- Ice rafting
- Aeolian
- Other

Distribution of Each Process on Bank

Process 1
- Toe
- Lower bank
- Upper bank
- Whole bank

Process 2
- Toe
- Lower bank
- Upper bank
- Whole bank

Process 3
- Toe
- Lower bank
- Upper bank
- Whole bank

Process 4
- Toe
- Lower bank
- Upper bank
- Whole bank

PART 11: LEFT BANK FAILURE MECHANICS

Status
- Stable
- Unreliable
- Unstable

Severity
- Insignificant
- Moderate
- Serious

Extent
- Toe
- Lower bank
- Upper bank
- Whole bank

Frequency
- None
- Occasional
- Frequent

Location
- General
- Outside Meander
- Inside Meander
- Opposite a bar
- Behind a bar
- Opposite structure
- Adjacent structure
- Dnstream of structure
- Upstream of structure

Failure Mode
- Shallow slide
- Rotational slip
- Slab-type
- Pop-out failure
- Cantilever failure
- Piping
- Flow failure
- Ravelling

Distribution of Each Mode on Bank

Mode 1
- Toe
- Lower bank
- Upper bank
- Whole bank

Mode 2
- Toe
- Lower bank
- Upper bank
- Whole bank

Mode 3
- Toe
- Lower bank
- Upper bank
- Whole bank

Mode 4
- Toe
- Lower bank
- Upper bank
- Whole bank

PART 12: LEFT BANK BERM CHARACTERISTICS

Present Status
- No berm
- small berm
- medium berm
- large berm

Berm Location
- None
- Only inside bends
- Continuous

Berm Material Size Data
- D50 (mm)
- sorting coefficient

Berm Materials
- Silt/clay
- Sand/silt/clay
- Sand/silt
- Sand
- Sand/gravel
- Gravel
- Gravel/cobbles
- Cobbles
- Cobbles/boulders
- Boulders
- Bed rock

Berm Vegetation
- None
- Cleared
- Grass and flora
- Reeds and sedges
- Shrubs
- Saplings
- Trees

Age
- Imature
- Mature
- Old

Berm Tree Types
- None
- Alder
- Ash
- Birch
- Cottonwood
- Elm
- Beech
- Sweet gum
- Willow
- Other (specify)

Density
- None
- Sparce
- Medium
- Dense

Diversity
- Mono-stand
- Mixed
- Climax-vegetation

Spacing
- Continuous
- Close
- Wide

Health
- Healthy
- Unhealthy
- Dead

Height
- Short
- Medium
- Tall

Roots
- Normal
- Advantitious
- Exposed

SECTION 3 - RIGHT BANK SURVEY

PART 13: RIGHT BANK CHARACTERISTICS

Type
- Noncohesive
- Cohesive
- Composite
- Layered
- Even Layers
- Thick+thin layers
- Number of layers

Protection Status
- Unprotected
- Hard points
- Revetments
- Dyke Fields

Bank Materials
- Silt/clay
- Sand/silt/clay
- Sand/silt
- Sand
- Sand/gravel
- Gravel
- Gravel/cobbles
- Cobbles
- Cobbles/boulders
- Boulders/bedrock

Mean Bank Height
- Average height (ft)

Mean Bank Slope
- Average angle (o)

Layer Thickness
- Material 1 (ft)
- Material 2 (ft)
- Material 3 (ft)
- Material 4 (ft)

Tension Cracks
- None
- Occasional
- Frequent

Crack Extent
- Proportion of bank height

Distribution and Description of Bank Materials in Bank Profile

Material Type 1	Material Type 2	Material Type 3	Material Type 4
Toe	Toe	Toe	Toe
Mid-Bnak	Mid-Bnak	Mid-Bnak	Mid-Bnak
Upper Bank	Upper Bank	Upper Bank	Upper Bank
Whole Bank	Whole Bank	Whole Bank	Whole Bank
D50 (mm)	D50 (mm)	D50 (mm)	D50 (mm)
sorting coefficient	sorting coefficient	sorting coefficient	sorting coef.

PART 14: RIGHT BANK-FACE VEGETATION

Vegetation
- None
- Cleared
- Grass and flora
- Reeds and sedges
- Shrubs
- Saplings
- Trees

Tree Types
- None
- Alder
- Ash
- Beech
- Birch
- Cottonwood
- Elm
- Sweet gum
- Willow

Density
- None
- Sparce
- Medium
- Dense

Spacing
- Continuous
- Close
- Wide

Location
- Whole bank
- Bank top
- Mid-bank
- Bank toe

Diversity
- Mono-stand
- Mixed
- Climax-vegetation

Health
- Healthy
- Fair
- Poor
- Dead

Age
- Imature
- Mature
- Old

Height
- Short
- Medium
- Tall

Extent
- Wide
- Medium
- Narrow

PART 15: RIGHT BANK EROSION PROCESSES

Status
- Intact
- Eroding
- Advancing

Severity
- Insignificant
- Mild
- Significant
- Serious
- Catastrophic

Extent
- Toe
- Lower bank
- Upper bank
- Whole bank

Estimated rate
- < 3ft/yr
- 3 - 10 ft/yr
- 10 - 25 ft/yr
- >25 ft/yr

Location
- General
- Outside Meander
- Inside Meander
- Opposite a bar
- Behind a bar
- Opposite a structure
- Adjacent to structure
- Dnstream of structure
- Upstream of structure
- Other

Processes
- Flow entrainment
- Piping
- Freeze/thaw
- Sheet erosion
- Rilling + gullying
- Wind waves
- Vessel Forces
- Ice rafting
- Aeolian
- Other

Distribution of Each Process on Bank

Process 1	Process 2
Toe	Toe
Lower bank	Lower bank
Upper bank	Upper bank
Whole bank	Whole bank

Process 3	Process 4
Toe	Toe
Lower bank	Lower bank
Upper bank	Upper bank
Whole bank	Whole bank

PART 16: RIGHT BANK FAILURE MECHANICS

Status
- Stable
- Unreliable
- Unstable

Severity
- Insignificant
- Moderate
- Serious

Extent
- Toe
- Lower bank
- Upper bank
- Whole bank

Frequency
- None
- Occasional
- Frequent

Location
- General
- Outside Meander
- Inside Meander
- Opposite a bar
- Behind a bar
- Opposite structure
- Adjacent structure
- Dnstream of structure
- Upstream of structure

Failure Mode
- Shallow slide
- Rotational slip
- Slab-type
- Pop-out failure
- Cantilever failure
- Piping
- Flow failure
- Ravelling

Distribution of Each Mode on Bank

Mode 1	Mode 2
Toe	Toe
Lower bank	Lower bank
Upper bank	Upper bank
Whole bank	Whole bank

Mode 3	Mode 4
Toe	Toe
Lower bank	Lower bank
Upper bank	Upper bank
Whole bank	Whole bank

PART 17: RIGHT BANK BERM CHARACTERISTICS

Present Status
- No berm
- small berm
- medium berm
- large berm

Berm Location
- None
- Only inside bends
- Continuous

Berm Material Size Data
- D50 (mm)
- sorting coefficient

Berm Materials
- Silt/clay
- Sand/silt/clay
- Sand/silt
- Sand
- Sand/gravel
- Gravel
- Gravel/cobbles
- Cobbles
- Cobbles/boulders
- Boulders
- Bed rock

Berm Vegetation
- None
- Cleared
- Grass and flora
- Reeds and sedges
- Shrubs
- Saplings
- Trees

Age
- Imature
- Mature
- Old

Berm Tree Types
- None
- Alder
- Ash
- Birch
- Cottonwood
- Elm
- Beech
- Sweet gum
- Willow
- Other (specify)

Density
- None
- Sparce
- Medium
- Dense

Diversity
- Mono-stand
- Mixed
- Climax-vegetation

Spacing
- Continuous
- Close
- Wide

Health
- Healthy
- Unhealthy
- Dead

Height
- Short
- Medium
- Tall

Roots
- Normal
- Advantitious
- Exposed

GUIDELINES ON THE USE OF SEDIMENTATION ANALYSIS SHEETS IN THE FIELD

1. BACKGROUND

1.1 Introduction

The nature and causes of sedimentation problems are often difficult to identify in the field. Even quite experienced river engineers and fluvial geomorphologists find it hard to describe the dominant sedimentary forms and features accurately. This is the case because sedimentation problems may result from a wide variety of dynamic channel processes, some operating at local scales, others at reach scales, and still others associated with instability of the entire fluvial system throughout the drainage basin.

Sediment erosion, transport and deposition usually takes place during high flows and it is not usually possible to observe these processes directly. Any opportunity to observe the river at high flow should be taken, as invaluable insights into sedimentation processes can be gained. However, often this simpiy is not possible.

Thus, during a site visit, the appearance of the channel, its geomorpholgical setting and the sedimentary forms and features must be used to infer the types of processes operating during channel forming flows, and judge the nature and severity of sediment related problems. The state of the channel on any particular visit depends to some extent on the sequence of erosion, failure and clean-out events in the days, weeks and months prior to the visit. Also, the cyclical nature of some sedimentary processes can produce a deceptive of stability in a changing channel. For example, continued bank erosion may occur by a cycle of flow under-cutting, mass failure and basal clean-out. This can produce parallel retreat, with little change in bank geometry over time. Consequently, a channel bank may appear unchanged on consecutive visits to a site, even though it has retreated substantially between the two visits. This is the case if it is at about the same stage of basal clean-out when the visits are made, there having been one or more mass failures in between. At first it appears that the bank has not moved since the previous visit, the actual retreat only becoming apparent when the position of the bank relative to fixed points or baselines is established. If such reference marks are not available it is all too easy to under-estimate the rapidity and severity of erosion and retreat.

Consequently, the channel and its surroundings must be examined carefully if it is to yield reliable pointers to the true nature of the dominant sedimentation forms and features, sedimentary processes, the impact of sediment problems and the resulting state of stability or instability. Usually the information necessary to make reliable estimates and interpretations is there, but the observer must know how and where to look for it.

The sedimentation analysis sheets presented here are an attempt to provide some assistance in examining alluvial streams, gathering the descriptive data necessary to characterize them, identifying the sediment processes and mechanisms, and estimating the severity of any problems. Only after these steps have been taken will it be possible to determine the cause of the problems with any confidence and make sound recommendations concerning remedial measures.

The sheets are not intended as a substitute for a conventional hydrographic, hydraulic and geotechnical survey of the site. Rather they are a fore-runner of such surveys and, being made over a wider area, they should allow any subsequent quantitative work to be targeted on critical areas to increase efficiency.

1.2 Overall Structure of the Sheets

The sheets are set out in three major sections, each on a separate page. *Section 1 - Valley and Channel Survey* deals with the broadest scale. The aims are: first to define the geologic, geomorphic and human environment around the channel, particularly by establishing the relationship between the river channel and its valley; second to establish a clear picture of the channel in terms of its characteristic dimensions, plan geometry, flow type, and bed and bar sediments; and third to determine the nature of the instability problem both in terms of severity and spatial extent. Reference is made here to vertical and lateral channel instability rather than just instability, because it is vital at this early stage to identify whether the direction of channel instability is in the vertical plane, horizontal plane, or both .

Section 2 - Left Bank Survey deals in greater detail with all aspects of bank assessment for the left bank. The aim is to establish a clear picture of the bank in terms of its characteristic geometry and materials, vegetation, erosion processes, failure mechanisms, and state of toe sediment balance. It is split into 5 parts dealing with each of these topics. *Section 3 - Right Bank Survey* repeats the survey for the other channel bank and completes the assessment.

1.3 Application of the Assessment Sheet Data

At present the data collected in the sedimentation analysis may be used in two ways. First, it may be addressed qualitatively by engineers and geomorphologists interested in establishing the channel characteristics and sediment impacts before making recommendations regarding the best approach to mitigating or preventing continued problems of channel sedimentation or instability. In this context, the sheets could form a useful component in the analysis of current river processes, instability and the prediction of river response to changes in flow regime or sediment transport. Use of the sheets would form part of the initial engineering/geomorphic analysis that is strongly recommended by most experts (see for example: Simons, Li and Associates, 1982; Schumm et al., 1984).

Second, the assessment sheets could be used to supply most of the input data required for the SAM approach to stable channel design being developed by WES (Thomas, 1990).

In this respect, the framework established here for characterizing the channel, its morphology and its sediments should be very useful in determining the applicability of the different equations for flow resistance, sediment transport and one-dimensional modeling. On this basis, the most appropriate quantitative approach to be used can be selected.

The sheets have the potential to form the input data for a computerized expert system on sedimentation analysis. To develop such a system is beyond the scope of the present project, but experience gained in the development and use of the field sheets should be very useful should such systems be developed in the future.

2. GUIDELINES FOR COMPLETING THE SHEETS

2.1 Introduction

In this section detailed guidance is given on how to fill-out the Sedimentation Analysis Sheets in the field. References to particular sections, parts and topics in the sheets are put in italics.

2.2 *Section 1 - Valley and Channel Survey*

This section deals with the geologic setting, geomorphic features and sedimentary characteristics of the river channel and its valley. It is essential to establish in order that sedimentation problems can be seen in the context of the general fluvial and sedimentary environment.

More particularly, it is important to establish any causal links between large-scale fluvial processes and sediment impacts at the outset, and to identify the severity and extent of any underlying instability in the fluvial system. Often the particular problem to be addressed in an analysis, such as bank erosion or bed aggradation, is just one manifestation of system instability and it should not then be treated in isolation if it is to be properly understood and dealt with.

This section is divided into 6 parts. Each is now dealt with in turn.

Part 1: Area around River Valley

Has six topics. The aim is to characterize the surrounding land in terms of terrain, geology, rock type, land-use, vegetation and forest type.

Terrain defines the type of land-scape within which the river valley is located. Generally, the greater the topography the more energy is available to do geomorphic work and the more rapid and pronounced will be terrain response to natural instability, or human-induced destabilisation.

Geology deals with the origin of the surficial materials making up the land-scape. Erosion resistance is directly related to surficial geology and this will strongly affect the susceptibility of the area to geomorphic processes and related sediment impacts.

Rock Type defines the composition of the sub-surface materials. Erosion resistance and sediment yield (both volume and calibre) are also affected by the rock type.

Land-use addresses the type of human activity taking place in the area around the valley. Generally, cultivated areas have higher run-off potential and sediment yields than natural catchments. Urban catchments produce flashy run-off hydrographs and altered sediment yields.

Vegetation plays an important role in catchment processes generating run-off and sediment yield. It is useful to know the types of vegetation in the catchment around the valley in order to gauge its influence on present catchment hydrology and sediment processes, and the potential for changes induced by changing land-use.

Forest Type has been shown to be an especially significant aspect of catchment vegetation in affecting catchment hydrology, soil stability and sediment production. The effects of coniferous versus deciduous forest are rather different, coniferous forests generally producing higher run-off and sediment yield due to the lack of a vegetative under-storey and the existence of drainage ditches and access roads, especially in plantations.

Part 2: Valley Sides

Has 6 topics. The aim is to define the scale, geometry, stability and mode of failure (if any) of the valley side slopes.

Height and *Side Slope Angle* define the scale and geometry of the valley sides. High and/or steep valley sides have the potential to be destabilized and to trigger system wide instability to the fluvial system.

Failures records whether the slopes are stable, or prone to occasional or frequent failures. Valley wall failures indicate lateral geomorphic activity, and possibly valley widening.

Severity of Problems indicates the level of activity of valley side wall failures. Severely unstable valley walls would be expected to be a major source of sediment in the fluvial system.

Failure Locations indicates whether failures are adjacent to, or remote from, the river channel. This critically important because it determines the relationship between the river and the failures, and indicates how sediments derived from valley side failures are delivered to the river. Failures occurring away from the river are not a direct result of river erosion. Sediments generated by such failures are stored as at the base of the slope for long periods (these deposits are called colluvium by geomorphologists).

They then either make their way to the river by very slow processes, such as soil creep, or are eroded during catastrophic floods - which occur only rarely. These failures are <u>uncoupled</u> from the fluvial system. Conversely, failures adjacent to the river are <u>coupled</u> directly to river erosion. They are triggered by flow undercutting and deliver large volumes of debris directly into the channel. Such failures may be considered to be bank erosion at the largest scale and may pose serious problems in terms of system stability, land loss and sediment yield.

Failure Types defines the mode of valley side failure. The type of failure determines the shape of the valley sided after failure, controls the volume of material involved in each failure and may help to identify the cause of the instability.

Part 43 Vertical Relation of Channel to Valley

This part has 10 topics. The aim is to establish the present relationship between the channel and its valley in terms of vertical relation, the dynamic nature of that relationship, and the existence of any landforms associated with vertical instability.

Present Status defines whether the river is currently adjusted to the present valley elevation (graded) or whether it is either incised (entrenched), or aggraded (numerous bars and islands, with a poorly defined channel). Incised rivers rarely flood, flow being concentrated in-channel even at very high discharges. They tend to have low width to depth (aspect) ratios and erode their banks through undercutting and mass failure. Aggrading rivers often flood, depositing sediment onto their flood plains (valley floors) They have high aspect ratios and widen through bank erosion by direct entrainment of bank material by the flow.

Instability: Status defines the severity of any vertical instability. This helps to put any sediment impacts associated with aggradation or degradation into perspective and is a first step towards prioritising channel instability problems in terms of urgency of stabilization.

Instability: extent defines the scale of vertical instability in the river. It is important at the outset to establish whether instability is a local, general or regional phenomenon. Usually, this is an essential step in identifying the underlying cause of a channel instability problem. It is also usually necessary to match the scale of the solution to the scale of the problem.

Terraces are fluvial landforms produced by vertical instability in the fluvial system. A terrace is a remnant of a former flood plain of the river, left which is no longer subject to inundation. It may be identified in the field as a strip of almost level ground above the elevation of the contemporary flood plain, and separated from that flood plain by a steeper scarp or slope. Terraces give the valley cross-profile a stepped appearance.

Number of Terraces records how many terraces may be identified. The theory of complex response shows how several terraces may be produced by a single destabilization of the system, as the river hunts for a new graded profile. The number of terraces indicates the nature and degree of past vertical instability and demonstrates the potential of the system for dynamic vertical activity.

Overbank Deposits notes the presence and size of material deposited directly onto the valley floor by out of bank flows. This information gives an idea of the frequency, magnitude and energy level of overbank flow.

Levees are produced by over bank sedimentation along the river during flood flows because the greatest amount of sediment tends to fall out of transport closer to the river. Well developed natural levees indicate a river with a heavy load of suspended sediment and frequent over-bank flooding. Man-made levees are constructed to contain flood flows are protect the area behind them from inundation. The presence of man-made levees indicates that the river is prone to frequent flooding in its natural state.

Levee Type indicates whether any levees present are natural or man-made.

Levee Data records the height and side slope angle of any levees present.

Levee Failures identifies the stability status of any levees present.

Part 4: Lateral Relation of Channel to Valley

This part has 7 topics. The aim is to establish the present relationship between the channel and its valley in terms of lateral relation, the dynamic nature of that relationship, the channel planform geometry and the nature and width of the valley floor.

Present Status defines whether or not the channel width is adjusted to the present flow regime. Adjusted channels have stable widths over time, although they may still evidence erosion of one bank and deposition at the other if they are laterally active. This is termed 'dynamic equilibrium'. Over-wide rivers are broad and shallow with shifting bars. They tend to have berms of accumulated sediment at both banks, producing a composite cross-sectional shape. Narrow rivers have low aspect ratios, no berms and more rectangular cross-sections.

Instability : Status defines the severity of any lateral instability. This helps to put any sediment impacts associated with bankline retreat and lateral shifting into perspective and is a first step towards prioritising channel instability problems in terms of urgency of stabilization.

Instability: extent defines the scale of lateral instability in the river. It is important at the outset to establish whether instability is a local, general or regional phenomenon. Usually, this is an essential step in identifying the underlying cause of a channel instability problem. It is also usually necessary to match the scale of the solution to the scale of the problem.

Planform describes the geometry of the channel when viewed from above. It uses the usual classification of rivers as being straight, meandering or braided. For single thread channels, sinuous channels are is the transition between straight and meandering. They have alternate bars and cut-banks opposite leading to curved flow, but have not yet attained a truly meandering course. Irregular meanders lack the symmetry of regular or classical meanders and usually indicate that the planform is being influenced by outcrops of erosion resistant materials in the banks. Tortuous meanders are highly convoluted and experience neck cut-offs. Braided rivers are very wide and shallow with divided flow around medial bars.

Planform Data records the characteristic dimensions of channel meanders. Bend radius measures the tightness of the bends in terms of the radius of a circle approximately following the channel centerline. Meander belt width is the width of the belt regularly swept by the channel as bends migrate downstream. Wavelength is twice the long valley distance between crossings (meander inflection points). Meander sinuosity is the ratio of channel length to straight line valley length between crossings.

Valley Floor Type establishes the existence and nature of the alluvial surface surrounding the river. If this is narrow and/or discontinuous then the potential exists for the river to destroy the flood plain bottom lands and attack the terraces and valley side slopes directly, potentially leading to severe instability of the whole valley system.

Valley Floor Data records the width of the valley floor relative to that of the channel.

Part 5: Channel Description

This part has 6 topics. The aims are to characterize the channel in terms of its dimensions, flow regime and geologic, sedimentary or man-made controls on bed scour and bank retreat. This supplies the basic information needed by a hydraulic engineer or geomorphologist to represent the river and its channel in terms of flow and potential for instability.

Dimensions gives an approximate guide to the size and shape of the channel in terms of the standard hydraulic geometry parameters such as average top bank width, average water surface width, average channel and water depths, reach slope, estimated mean velocity, and Manning's n.

Flow Type defines the regime of flow in the channel according to the principles of free surface flow. Uniform flow lacks major changes in flow velocity with distance along the channel. Tranquil flow is sub-critical, shooting flow super-critical. Pools and riffles are areas of deep and shallow flow respectively, which produce non-uniform flow. Tumbling flow occurs in steep streams with large bed material which disrupts the water surface and produces locally super-critical flow. Step-pool flow is found in very steep channels with boulders arranged in periodic steps across the channel and pools in between.

Bed Controls set limits on the degree of vertical instability allowed by the local geology, materials and/or human intervention. A control is a feature which is not easily eroded by the river, thereby preventing continued instability.

Control Types defines the nature of the bed controls. Examples are bed rock outcrops, coarse sediments which form an armor layer in the bed, and fine sediments which are strongly cohesive. Where natural controls like these are absent, weirs or cut-off walls may be constructed to prevent bed degradation. Such *grade control structures* are a vital where degradation may occur and natural controls are either absent or unreliable. Aprons constructed at bridges and culverts may also act as grade controls.

Width Controls set limits on the degree of widening and/or lateral migration allowed by the local geology, materials and human intervention. A control is a feature which is not easily eroded by the river, thereby preventing continued lateral erosion. Where natural controls are inadequate man-made structures such as revetments or dykes may be used to prevent bankline movement. Lateral shifting may also be constrained at bridge crossings.

Control Types define the nature of the width controls. Examples are bed rock outcrops, coarse sediments which form an armour layer on the bank, and fine sediments which are strongly cohesive. Controls due to fine sediments are often associated with clay plugs and back swamp deposits in the flood plain left by earlier depositional activity. Where natural controls like these are inadequate, dyke fields and/or revetments may be used to control river width. and bankline movement Such *training structures* are a vital part of bank protection schemes in systems where width is unstable and natural controls are either absent or unreliable.

Part 7: Bed Sediment Description

This part has 10 topics. The aims are to characterize the sediments in the bed and bars of the channel in terms of their types, stratigraphy, depth, size distributions, bed forms, bar types. This supplies the basic information needed by a hydraulic engineer or geomorphologist to represent the river sediments when calculating sediment transport and potential for bed instability.

Bed Material characterizes the bed sediment of the river. It is recognized that their are fundamental differences in the flow and sedimentary regimes and responses of rivers with markedly different bed materials.

Bed Armor verities whether a coarse surface layer is present. Armoring plays a vital role in determining the availability of bed sediments for transport by the flow. The armor may be static - that is immobile under all but catastrophic flood flows, or mobile - that is mobile at flows below bankfull discharge.

Sediment Depth records the depth of loose sediment in the bed of the channel. This gives a guide to the size of the reservoir of sediment stored in the channel and available for transport by the flow. Degrading channels have very thin bed sediment thicknesses, while aggrading channels have great thicknesses.

Surface and Substrate Size Data are based on size analyses of bed material samples taken at a representative point in the bed. This should be at about mid-channel in a crossing, away from obvious bar and island features. A separate substrate sample is only necessary if an armor layer is present.

Bed Forms notes the presence and type of bed forms in the bed of the channel. Bed forms are very important in producing form roughness which increases the Manning's n for a channel and play a significant role in the movement of sediment as bed load.

Islands or bars accounts for the presence of divided reaches in the flow. Divided flows are generally less hydraulically efficient than single channel flows. Islands and bars have important impacts on flow resistance and channel capacity.

Bar Types describes the morphology of any bars. Bars represent major topographic features in the channel bed and are intimately related to flow patterns and sediment transport distributions. They are often responsible for diversion of the flow so that it attacks one or both banks, promoting erosion, basal scour and bank retreat.

Bar Surface and Substrate Data are based on size analyses of bar material samples taken at a representative point on the bar. This should be at about mid-bar, away from obvious bar head and bar tail. A separate substrate sample is only necessary if an armor layer is present. Bars are often the primary source of sediment for transport by the river, especially in rivers with armored beds.

2.3 Section 2 - Left Bank Survey

This section describes in detail the character, vegetation, erosion processes, failure mechanics and toe-sediment balance for the left bank. It is divided into 5 parts, dealing with each of these aspects in turn. A complete and thorough evaluation of the bank and its dynamics lies at the heart of the field inspection and forms the basis for the explanation of bankline retreat and the establishment of the best approaches to modeling erosion processes and selecting stabilization strategies.

It is very important that the user complete each section independently of the information gathered in other sections. For example, the status of bank stability with regard to mass failure is not addressed until Part 11. Users should not allow the presence or absence of failures influence their selections in parts 8 to 10 which do not deal with bank failures but with other characteristics and processes.

Berms are basal accumulations of sediment at the toe of the bank. They are an important morphological feature of alluvial channels and are dealt with in part 12, separately from the intact bank.

Part 8: Left Bank Characteristics

This part contains 12 topics. The aim is is characterize the left bank in terms of its approximate dimensions, geometry, materials and stratigraphy. All of these characteristics are of fundamental importance to bank erosion, failure and stabilization.

Type establishes the overall classification of the bank as being noncohesive, cohesive, composite or layered. Research on bank erosion has illustrated basic differences between banks formed in different materials, or combinations of materials. Noncohesive banks are formed in sands, gravels, cobbles and boulders that lack any intrinsic cohesion. Cohesive banks are formed in silts and clays which are cohesive. Composite banks consist of a single cohesive layer underlain by a single noncohesive layer. Such banks are common in rivers with noncohesive bed material (sand or gravel) which are flowing through alluvial flood plain deposits consisting of bed material overlain by overbank fines deposits. Layered banks consist of layers of noncohesive and cohesive materials laid down during a past aggradational phase. Often the layers are of uneven thickness and this can be very significant to bank erosion and hydrology.

Protection Status Bank establishes whether the bank is unprotected or has been subject to engineering stabilization.

Bank Materials details the composition of the bank in terms of the characteristic types of sediment for up to four materials that make up the bank. This supplies vital information on the nature of the bank materials for interpreting bank erosion and failure processes.

Mean Bank Height and Mean Bank Slope records the approximate parameters necessary to define the size and steepness of the bank.

Layer Thickness records the thickness of each stratigraphic unit making up the bank.

Tension Cracks notes whether there are tension cracks behind the bank. Tension cracks develop vertically down from the ground surface behind steep banks and greatly reduce the stability of the bank with respect to mass failure.

Crack Extent records the depth of tension cracking as a proportion of the total bank height.*t*

Distribution of Bank Materials in Bank Profile (Material Types 1 - 4) defines the distribution of the bank materials through the bank. This can be of crucial importance. For example, the occurrence of a weak, noncohesive layer close to top of a layered bank is of little consequence, but that same layer at the toe would lead to rapid undermining and failure.

Part 7: Left Bank Vegetation

This part has 10 topics. The role of bank vegetation in affecting bank processes and stability has been recognized by engineers and geomorphologists alike. Vegetation effects may be either beneficial or detrimental to bank stability depending on the nature of the vegetation and the geomorphic environment. It is therefore necessary to for vegetation to be covered in some detail in the description of the bank.

Vegetation at the broad scale classifies the types of flora found on the bank.

Tree Types recognizes that particular species of tree are more or less effective in stabilizing the bank, while others often cause instability.

Density describes the degree of vegetative cover over the bank face. Particularly, it refers to the relative percentages of bare soil versus that covered by plants. The higher the density, the better the vegetative protection, but also the greater the flow retardance.

Spacing describes how the vegetation is spread over the bank. Particularly, it refers to whether there are clumps of vegetation with spaces in between which the flow might attack, or whether there is an close spacing of plants. It differs from density. For example, it is quite possible for dense vegetation to be growing in widely spaced clumps with bare spaces in between.

Location defines the position of the vegetation on the bank profile. Generally, vegetation at the bank top is less effective in stabilizing the bank than that lower on the bank.

Diversity deals with the mix of vegetative types present. Generally a mature ecosystem is more beneficial than a monostand.

Health identifies the state of the vegetation. Dead or dying vegetation quickly becomes a serious liability to bank stability.

Age can be a useful guide to the history of the bank. Mature vegetation clearly can only develop on a stable bank, while a predominance of young, immature vegetation hints at recent instability.

Height is a factor in determining the effect of vegetation in dragging down the bank and in impeding near bank flow in the channel. Tall trees may drag down a section of bank by toppling into the channel through either their surcharge weight or due to wind-throw.

Extent describes the width of the band of bank vegetation along the channel. It refers to how extensive the band of vegetation is in relation to the riparian corridor. A wide, extensive band produces a buffer zone along the bank which isolates it from the flood plain and has many advantages to the bank environment and its stability. A narrow band is grazed on the bankward side only, producing asymmetrical trees and bushes which lean over into the channel and are vulnerable to destabilization by wind-throw.

Part 10: Left Bank Processes

This part has 10 topics. The aim is to develop a good understanding of the process responsible for erosion and their distribution over the bank, both along the channel and up and down the bank profile.

Status establishes whether the bank is intact, eroding or advancing (due to sediment deposition).

Severity puts any erosion into perspective. Nearly all rivers have some bank erosion, but by no means all merit analysis or treatment.

Extent locates the erosion over the bank profile. Generally, toe erosion is most serious to overall bank retreat potential.

Estimated Rate gives a general idea of the seriousness of the problem. The rate may be estimated using historical information (maps, aerial photographs), reference to the position of the bank relative to fixed points on repeated visits, or sound local knowledge from a reliable source. In this respect the opinions of the land owner should be accepted with caution and checked against independent estimates.

Location establishes the position of the eroding area in relation to major channel features. These may, or may not, be the cause of the problem.

Processes attempts to identify the erosive processes responsible. This is not an easy task and often requires some training. It is assumed here that the individuals undertaking the survey are somewhat familiar with erosion processes and recognition of the effects of different processes on the bank surface. Some guidance is necessary though:

Flow entrainment is the detachment and removal of intact grains or aggregates of grains from the bank face by the flow. Evidence includes: impingement of high velocity flow against the bank; a fresh, ragged appearance to the bank face; undercutting of the toe/lower bank relative to the bank top; a lack of surficial bank vegetation.

Piping is the caused by groundwater seeping out of the bank face. Grains are detached and entrained by the seepage flow (termed sapping) and may be transported away from the bank face by surface run-off generated by the seepage, if their is sufficient volume of flow. Evidence includes: pronounced seep lines, especially along sand layers or lenses in the bank; pipe shaped cavities in the bank, notches in the bank associated with seepage zones, run-out deposits of eroded material on the lower bank or berm. Note that the effects of piping erosion can easily be mistaken for those of wave and vessel force erosion.

Freeze/thaw is caused by sub-zero temperatures which promote freezing of the bank material. Ice wedging cleaves apart blocks of soil. Needle-ice formation loosens and detaches grains and crumbs at the bank face. Evidence includes: periods of below freezing temperatures in the river valley; jumbled blocks of bank material; a loose crumbling appearance to the bank surface; loosened crumbs accumulated at the foot of the bank after a frost event.

Sheet erosion is the removal of a surface layer of soil by non-channelized surface run-off. It results from surface water drainage over the bank. Evidence includes: lack of vegetation cover, fresh new appearance to the soil surface; eroded material accumulated on the lower bank/toe area.

Rilling + gullying occurs when there is sufficient uncontrolled surface run-off over the bank to initialize channelized erosion. Evidence includes: a corrugated appearance to the bank surface due to closely spaced rills; larger gullied channels incised into the bank face, headward erosion of small tributary gullies into the flood plain surface.

Wind wave erosion is only likely on large rivers with long fetches to allow the build up of significant waves. Evidence includes: large channel width or long,straight channel and acute angle between eroding bank and longstream direction; wave-cut notch at about normal low water plane; wave-cut platform or berm below normal low-water plane. Note that it is easy to mistake the notch and platform produced by piping and sapping for one cut by wave action (see papers by Hagerty and Hagerty, 1989 and by May, 1982).

Vessel Forces can generate bank erosion in a number of ways. The most obvious way is through the generation of surface waves at the bow and stern which run up against the bank in the same fashion as wind waves. In the case of large vessels and/or high speeds these waves may be very damaging. If the size of the vessel is large compared to the dimensions of the channel, then hydrodynamic effects produce surges and drawdown in the flow. These rapid changes in water level too can loosen and erode material on the banks. If the vessels are relatively close to the bank prop. wash can erode material and re-suspend sediments on the bank below the water surface. Finally, mooring vessels along the bank may involve mechanical damage by the hull. Evidence includes: use of river for navigation; large vessels moving close to the bank, high speeds, observation of significant vessel induced waves and surges; a wave-cut notch at the normal low-water plane; a wave-cut platform or berm below normal low-water plane. Note that it is easy to mistake the notch and platform produced by piping and sapping for one cut by vessel forces (see papers by Hagerty and Hagerty, 1989 and by May, 1982).

Ice rafting erodes the banks through mechanical damage to the banks due to the impact of ice-masses floating in the river and due to surcharging by ice cantilevers during spring thaw. Evidence includes: severe winters with river prone to icing over; gouges and disruption to the bank line; topping and cantilever failures of bank during spring break-up.

Aeolian erosion is caused by the wind entraining grains from the bank face or slip-off slope. It will only be significant where vegetation cover is sparce or absent due to the action of other more virulent erosion processes such as flow entrainment or piping. Evidence includes: bare soil surfaces and fine, granular materials; dust and sand blowing around; sediment deposits in areas sheltered from the wind.

Other erosion processes could potentially be significant but it is impossible to list them all individually. If some other erosive process is identified, tick this box and write it in below the box.

Distribution of Each Process on the Bank recognizes that different processes may be responsible for eroding different parts of the bank. The distribution of up to four different processes over the bank may be delineated here. This is significant because the distribution of different erosion processes has geomorphic implications and may require special consideration when stabilizing the bank.

Part 11: Left Bank Failure Mechanics

This part has 10 topics. The aim is to develop a good understanding of the modes of failure involved in bank retreat and their distribution over the bank, both along the channel and up and down the bank profile.

Status establishes state of stability with regard to mass failure.

Severity puts any instability into perspective. Nearly all rivers have some bank instability, but by no means all merit analysis or treatment.

Extent locates the instability over the bank profile. Generally, whole bank and lower bank failures are most serious to overall bank retreat potential.

Frequency gauges the number of failures observed along the study reach.

Location establishes the position of the failure(s) in relation to major channel features. These may, or may not, be the cause of the problem.

Failure Mode attempts to identify the type of failures resulting from bank instability. This is not an easy task and often requires some training. It is assumed here that the individuals undertaking the survey are somewhat familiar with failure mechanics and recognition of the geometry of the bank which results from different mechanisms. Some guidance is necessary though:

Shallow slide is a shallow seated failure along a plane somewhat parallel to the ground surface. Such failures are common on banks of low cohesion. Shallow slides often occur as secondary failures following rotational slips and/or slab failures. Evidence includes: weakly cohesive bank materials; thin slide layers relative to their area; planar failure surface; no rotation or toppling of failure mass.

Rotational slip is the mass failure mode most commonly dealt with in geotechnical engineering. A deep seated failure along a curved surface results in back-tilting of the failed mass toward the bank. Such failures are common in cohesive banks with angle below about 60°. Evidence includes: cohesive bank materials; deep seated, curved failure surface; back-tilting of top of failure mass towards intact bank; arcuate shape to intact bank line behind failure mass.

Slab-type failure is the forward toppling of a deep seated mass into the channel. Often there are deep tension cracks in the bank behind the failure block. Slab failures occur in cohesive banks with steep bank angles, greater than about 60°. Evidence includes: cohesive bank materials; deep seated failure surface with a planar lower slope and near vertical upper slope; tension cracks behind the bankline; forward tilting of failure mass into channel; planar shape to intact bankline behind failure mass.

Pop-out failure results from strong seepage in a steep, cohesive bank. A slab of material in the lower half of the steep bank face pops out, leaving an alcove shaped cavity. The overhanging roof of the alcove subsequently collapses as a cantilever type failure. Evidence includes: cohesive bank materials; steep bank face with seep area low in the bank; alcove shaped cavities in bank face.

Cantilever failure is the collapse of an overhanging block into the channel. Such failures occur in composite and layered banks where a strongly cohesive layer is underlain by a less resistant one. Under-mining by flow erosion, piping, wave action or pop-out failure leaves an overhang which collapses by a beam, shear or tensile failure. Evidence includes: composite or layered bank stratigraphy; cohesive layer underlain by less resistant layer; under-mining; overhanging bank blocks; failed blocks on the lower bank and at the bank toe.

Piping failure is the collapse of part of the bank due to high groundwater seepage pressures and rates of flow. Such failures are an extension of the piping process described earlier to the point that there is loss of strength in the seepage layer. Sections of bank disintegrate, are entrained by the seepage flow (termed sapping) and may be transported away from the bank face by surface run-off generated by the seepage, if their is sufficient volume of flow. Evidence includes: pronounced seep lines, especially along sand layers or lenses in the bank; pipe shaped cavities in the bank, notches in the bank associated with seepage zones, run-out deposits of eroded material on the lower bank or berm. Note that the effects of piping failure can easily be mistaken for those of wave and vessel force erosion.

Flow failure is the loss of strength of a section of bank due to saturation. Such failures occur when water logging of the bank increases its weight and decreases its strength to the point that the soil flows as a highly viscous liquid. This may occur following heavy and prolonged precipitation, snow melt or rapid drawdown in the channel. Evidence includes: sections of bank which have sloughed at very low angles; areas of formerly flowing soil that have been preserved when he soil dried out; basal accumulations of soil showing delta-like patterns and structures.

Ravelling describes the flow-type failure of a dry, granular bank material. Other terms are soil fall and soil avalanche. Such failures occur when a noncohesive bank at close to the angle of repose is undercut, increasing the local bank angle above the friction angle. A carpet of grains rolls, slides and bounces down the bank in a layer up to a few grains thick. Evidence includes: noncohesive bank materials; bank angle close to the angle of repose; undercutting, basal accumulations of loose grains in cones and fans.

Distribution of Each Mode on the Bank recognizes that different failure modes may be involved in the collapse of different parts of the bank. The distribution of up to four different modes over the bank may be delineated here. This is significant because the distribution of different failure modes has geomorphic implications and may require special consideration when stabilizing the bank.

Part 12: Left Bank Berm Characteristics

The part has 13 topics. The aims are to characterize the balance between sediment supply and removal at the bank toe and to establish the degree of berm development there. The sediment balance defines the state of basal endpoint control of the bank. Banks which have net toe erosion are certain to become less stable and to retreat more rapidly in the future unless a more resistant bank material is encountered or steps are taken to stabilize the bank. When stabilizing such banks, special steps must be taken to eliminate continued toe erosion.

Banks which have neither net toe erosion or deposition will continue to retreat at about a constant rate. Only the usual degree of toe scour protection is needed on such banks.

Banks with net toe deposition should show increased stability and a reduced rate of retreat, all else being equal. This is achieved through berm building - the accumulation of a low angle sediment wedge at the bank toe. Hence the degree of berm development is a good indicator of the tendency of the bank towards stability. Given the opportunity, vegetation invades stable berms quite quickly. Therefore, berm vegetation can be used as a guide to the age and permanence of a berm.

Banks with developing, permanent berms should not normally require structural bank protection.

Status establishes the presence or absence of a berm at the bank toe.

Berm Location describes whether a berm is found all along the bank or only inside bends. Often, local erosion at the outer bank in bendways destroys berms in those locations.

Berm Material Size Data records the size distribution of a representative sample of berm sediment.

Berm Materials describes the composition of the berm in terms of the characteristic materials that make up the berm. This supplies vital information on the nature of the berm materials for interpreting berm processes.

Berm Vegetation at the broad scale classifies the types of flora found on the berm.

Age can be a useful guide to the history of the berm. Old and mature vegetation clearly can only develop on a stable berm, while a predominance of young, immature vegetation hints at a recently deposited berm that may be a temporary feature, being destroyed at high flow.

Berm Tree Types recognizes that particular species of tree are more or less effective in stabilizing the berm, while others often cause instability and obstruct the flow.

Density describes the degree of vegetative cover over the berm. The higher the density, the better the vegetative protection and the greater the trap efficiency of the vegetation in inducing further berm deposition, but also the greater the retardance of high in-bank flows.

Diversity deals with the mix of vegetative types present. A more mature ecosystem has increased diversity indicating that there has been a long period of berm stability.

Health identifies the state of the berm vegetation. Dead or dying vegetation quickly becomes a serious liability to berm and channel stability.

Height is a factor in determining the effect of vegetation in impeding near bank flow in the channel and promoting berm sedimentation.

Roots defines the relationship between the vegetation roots and the berm surface. If the elevation of the berm surface has not changed substantially, then the roots are found just below the surface. If the berm is growing, vegetation produces Adventitious roots into the new sediment as this moves the ground surface up relative to the plant. If the berm is eroding, plant roots are exposed as the ground surface moves down relative to the plant. Hence the state of the roots can be used to infer the present trend in berm growth or erosion.

4.2.4 Section 3- Right Bank Survey

Section 3 repeats the bank survey for the other river bank. The section consists of parts 13 to 17 which are indentical to parts 8 to 12 in section 2.

3. CONCLUSION

The sedimentation analysis sheets presented here are a first attempt to develop a system to observe and record information pertaining to sediment impacts and problems on natural water courses. They are to be tested and modified in the light of experience. Any individual who uses the sheets should bear in mind their preliminary nature. Any experience with the sheets would be of interest to the developers, who would be grateful for feedback and comments. Please address any correspondence to either of the investigator named on the front cover of this document or the relevant staff at WES.

5.5 REFERENCES

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APPENDIX B

Recommended Contents for a Field Equipment Backpack

Field Equipment Backpack

Equipment	Primary Usage	Cost ($)
Backpack	Transporting equipment and protecting it from the weather and accidental damage	27.50
Sunto Compass (metal)	Finding direction, orientating maps and aerial photographs, taking bearings, establishing baselines.	61.00
Sunto Clinometer	Measuring valley side and bank slopes. Measuring bank and tree heights	187.75
Range-finder	Measuring distances such as channel width and longstream reach length, where access is difficult.	66.75
Lietz Open Reel Tape	Measuring distances such as channel width and longstream reach length, where access is easy.	24.50
Lietz 5x Mag. Hand Level	Leveling cross-sections, bank profiles and long-stream bed and water slopes.	99.00
Lietz Level Rod	Leveling cross-sections, bank profiles and long-stream bed and water slopes.	122.50
Chaining Pins	Marking sections and points of interest.	33.70
Sunglo Vinyl Flagging	Flagging features of interest.	3.00
Stop Watch	Timing transit time of floats for velocity measurement.	not known
Hammer/Hatchet	Clearing brush, hammering pegs.	31.50
Army Trenching Shovel	Digging sample pits and trenches.	5.00
Soil sample Bags (100)	Holding bed, bar and bank material samples.	11.95
Marker Pen	Labeling sediment samples.	1.00
Sieve Screen Set (6 sieves)	On-site sieve analysis of sediment samples	54.50

TOTAL COST OF FIELD BACKPACK (EXCLUDING STOPWATCH) $729.65

NOTE. All field groups should also be equipped with a first aid kit, insect repellent, sun screen and clothing and footwear appropriate to the field area and weather.

APPENDIX C Completed Sedimentation Assessment Sheets for Clear Creek, Bovina, Mississippi

SEDIMENTATION ANALYSIS SHEET
Developed by Colin R. Thorne
for the US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

RIVER CLEAR CREEK — SITE BOVINA — REACH From FARRAH BR. To TIFTONTOWN BR

SHEET COMPLETED BY GROUPS 4,5,6 — DATE 10/18/90 — TIME: START 2:15 pm — TIME: FINISH 4:40 pm

SECTION 1 - VALLEY AND CHANNEL SURVEY

PART 1: AREA AROUND RIVER VALLEY

Terrain: Mountains ☐ · Uplands ☐ · Hills ☒ · Plains ☐ · Lowlands ☐

Geology: Bed rock ☐ · Moraine ☐ · Glacio/Fluvial ☐ · Fluvial ☒ · Lacustrine ☐ · Wind blown (loess) ☒

Rock Type: Cemented Clay ☐ · Shale ☐ · Limestone ☐ · Sandstone ☐ · Conglomerate ☐ · Granite ☐ — NO ROCK

Land Use: Natural ☒ · Cultivated ☒ · Urban ☐

Vegetation: None ☐ · Grass ☒ · Arable Crops ☐ · Shrubs ☐ · Forest ☒

Forest Type: None ☐ · Deciduous ☐ · Coniferous ☐ · Mixed ☒

PART 2: VALLEY SIDES

Height: < 20 feet ☐ · 20-50 feet ☒ · 50-100 feet ☐ · >100 feet ☐

Side Slope Angle: < 30 degrees ☒ · 30-60 degrees ☐ · >60 degrees ☐

Valley side Failures: None ☒ · Occasional ☐ · Frequent ☐

Severity of Problems: Insignificant ☒ · Moderate ☐ · Serious ☐

Failure Locations: None ☒ · Away from river ☒ · Along river (Undercut) ☐

Failure Types: None ☐ · Shallow slide ☐ · Rotational slip ☐ · Slab-type ☐ · Piping ☐ · Flow failure ☐

PART 3: VERTICAL RELATION OF CHANNEL TO VALLEY

Present status: Adjusted ☐ · Incised ☒ · Aggraded ☐

Instability:Status: Insignificant ☒ · Moderate ☒ · Serious ☐

Instability:extent: None ☒ · Local ☐ · General ☐ · Reach scale ☐ · System wide ☐ · Regional scale ☐

Terraces: None ☒ · Indefinate ☐ · Fragmentary ☐ · Continuous ☐ · Number of terraces ☐

Number of Terraces: Number above valley Floor ☐

Overbank Deposits: None ☒ · Silt ☐ · Fine sand ☐ · Medium sand ☐ · Coarse sand ☐ · Gravel ☐

Levees: None ☐ · Indefinate ☐ · Fragmentary ☐ · Continuous ☒

Levee Type: Natural ☐ · Man-made ☒ (Road)

Levee Data: Height (f) 4 · Side Slope (o) ☐

Levee Failures: None ☒ · Occasional ☐ · Frequent ☐

PART 4: LATERAL RELATION OF CHANNEL TO VALLEY

Present Status: Adjusted ☒ · over wide ☐ · narrow ☐

Instability:Status: Insignificant ☐ · Moderate ☒ · Serious ☐

Instability:extent: None ☐ · Local ☐ · General ☒ · Reach scale ☐ · System wide ☐ · Regional scale ☐

Planform: Straight ☐ · Sinuous ☐ · Irregular ☐ · Regular meanders ☒ · Irregular meanders ☐ · Tortuous meanders ☐ · Braided ☐

Planform Data: Bend Radius ☐ 200-250 ft · Meander belt width ☐ 500-1000 · Wavelength ☐ 600 · Meander Sinuosity ☐ 1.65

Valley Floor Type: None ☐ · Indefinate ☐ · Fragmentary ☐ · Continuous ☐

Valley Floor Data: < 1 river width ☐ · 1 - 5 river widths ☐ · > 5 river widths ☒

Note: width = channel top width

PART 5: CHANNEL DESCRIPTION

Dimensions: Ave. top bank width ☐ 120-140 ft · Ave. channel depth ☐ 10 · Ave. water width ☐ 45-50 ft · Ave. water depth ☐ 4-5 ft · Reach slope ☐ 0.005 · Mean velocity ☐ 2 ft/s · Manning's n value ☐ 0.04

Flow Type: None ☐ · Uniform/Tranquil ☒ · Uniform/Rapid ☐ · Pool+Riffle ☐ · Tumbling ☐ · Step-pool ☐

Bed Controls: None ☒ · Occasional ☐ · Frequent ☐ · Confined ☐ · Number of controls ☐

Control Types: None ☐ · Bedrock ☐ · Boulders ☐ · Gravel armor ☐ · Bridge aprons ☐ · Grade control structures ☐

Width Controls: None ☐ · Occasional ☐ · Frequent ☐ · Confined ☐ · Number of controls ☐

Control Types: None ☐ · Bedrock ☐ · Boulders ☐ · Gravel armor ☐ · Revetments ☐ · Bridge abutments ☒ (Rip Rap →) · dykes or groynes ☐

PART 7: BED SEDIMENT DESCRIPTION

Bed Material: Silt ☒ · Sand ☒ · Sand and gravel ☒ · gravel and cobbles ☐ · cobbles + boulders ☐ · boulders + bedrock ☐ · Bed rock ☐

Bed Armour: None ☐ · Static-armour ☐ · Mobile-armour ☒

Sediment Depth: Depth of loose Sediment in bed (ft) 2 in thalweg

Surface Size Data: D50 (mm) ☐ · D84 (mm) ☐ · sorting coefficient ☐

Substrate Size Data: D50 (mm) ☐ · D84 (mm) ☐ · sorting coefficient ☐

Bed Forms: Plane bed ☒ · Ripples ☐ · Dunes ☐ · Bed form height (ft) ☐

Island or Bars: None ☐ · Occasional ☒ · Frequent ☐

Bar Types: None ☐ · Pools and riffles ☐ · Alternate bars ☒ · Point bars ☒ · Mid-channel bars ☐ · Diagonal bars ☐ · Sand waves + dunes ☐

Bar Surface data: D50 (mm) ☐ · D84 (mm) ☐ · sorting coef. ☐

Bar Substrate data: D50 (mm) ☐ · D84 (mm) ☐ · sorting coef. ☐

Subreach 1

SECTION 2 - LEFT BANK SURVEY

PART 8: LEFT BANK CHARACTERISTICS

Type
- Noncohesive [X]
- Cohesive [ ]
- Composite [ ]
- Layered [X]
- Even Layers [ ]
- Thick+thin layers [ ]
- Number of layers [2]

Protection Status
- Unprotected [X]
- Hard points [ ]
- Revetments [ ]
- Dyke Fields [ ]

Bank Materials
- Silt/clay [ ]
- Sand/silt/clay [X] 1
- Sand/silt [ ]
- Sand [X] 2
- Sand/gravel [ ]
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders/bedrock [ ]

Mean Bank Height
- Average height (ft) [11]

Mean Bank Slope
- Average angle (o) [25] 35%

Layer Thickness
- Material 1 (ft) [2]
- Material 2 (ft) [9]
- Material 3 (ft) [ ]
- Material 4 (ft) [ ]

Tension Cracks
- None [X]
- Occasional [ ]
- Frequent [ ]

Crack Extent
- Proportion of bank height [ ]

Distribution and Description of Bank Materials in Bank Profile

	Material Type 1	Material Type 2	Material Type 3	Material Type 4
Toe	[X]	[ ]	[ ]	[ ]
Mid-Bnak	[X]	[X]	[ ]	[ ]
Upper Bank	[ ]	[X]	[ ]	[ ]
Whole Bank	[ ]	[ ]	[ ]	[ ]
D50 (mm)	[ ]	[ ]	[ ]	[ ]
sorting coefficient	[ ]	[ ]	[ ]	[ ]

PART 9: LEFT BANK-FACE VEGETATION

Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [X]
- Reeds and sedges [ ]
- Shrubs [X]
- Saplings [X]
- Trees [X]

Tree Types
- None [ ]
- Alder [ ]
- Ash [ ]
- Beech [ ]
- Birch [ ]
- Cottonwood [ ]
- Elm [ ]
- Sweet gum [ ]
- Willow [X]

Density
- None [ ]
- Sparce [ ]
- Medium [ ]
- Dense [X] Trees

Spacing
- Continuous [ ]
- Close [X] Trees
- Wide [ ]

Location
- Whole bank [X]
- Bank top [ ]
- Mid-bank [ ]
- Bank toe [ ]

Diversity
- Mono-stand [ ]
- Mixed [ ]
- Climax-vegetation [X]

Health
- Healthy [X]
- Fair [ ]
- Poor [ ]
- Dead [ ]

Age
- Imature [ ]
- Mature [X]
- Old [ ]

Height
- Short [X]
- Medium [ ]
- Tall [ ]

Extent
- Wide [ ]
- Medium [ ]
- Narrow [ ]

PART 10: LEFT BANK EROSION PROCESSES

Status
- Intact [ ]
- Eroding [ ]
- Advancing [X]

Severity
- Insignificant [ ]
- Mild [X]
- Significant [ ]
- Serious [ ]
- Catastrophic [ ]

Extent
- Toe [ ]
- Lower bank [X]
- Upper bank [ ]
- Whole bank [ ]

Estimated rate
- < 3ft/yr [X]
- 3 - 10 ft/yr [ ]
- 10 - 25 ft/yr [ ]
- >25 ft/yr [ ]

Location
- General [X]
- Outside Meander [ ]
- Inside Meander [ ]
- Opposite a bar [ ]
- Behind a bar [ ]
- Opposite a structure [ ]
- Adjacent to structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]
- Other [ ]

Processes
- Flow entrainment [ ]
- Piping [ ]
- Freeze/thaw [ ]
- Sheet erosion [ ]
- Rilling + gullying [ ]
- Wind waves [ ]
- Vessel Forces [ ]
- Ice rafting [ ]
- Aeolian [ ]
- Other [ ]

Distribution of Each Process on Bank

	Process 1	Process 2	Process 3	Process 4
Toe	[ ]	[ ]	[ ]	[ ]
Lower bank	[ ]	[ ]	[ ]	[ ]
Upper bank	[ ]	[ ]	[ ]	[ ]
Whole bank	[ ]	[ ]	[ ]	[ ]

PART 11: LEFT BANK FAILURE MECHANICS

Status
- Stable [X]
- Unreliable [ ]
- Unstable [ ]

Severity
- Insignificant [X]
- Moderate [ ]
- Serious [ ]

Extent
- Toe [ ]
- Lower bank [ ]
- Upper bank [ ]
- Whole bank [ ]

Frequency
- None [ ]
- Occasional [ ]
- Frequent [ ]

Location
- General [ ]
- Outside Meander [ ]
- Inside Meander [ ]
- Opposite a bar [ ]
- Behind a bar [ ]
- Opposite structure [ ]
- Adjacent structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]

Failure Mode
- Shallow slide [ ]
- Rotational slip [ ]
- Slab-type [ ]
- Pop-out failure [ ]
- Cantilever failure [ ]
- Piping [ ]
- Flow failure [ ]
- Ravelling [ ]

Distribution of Each Mode on Bank

	Mode 1	Mode 2	Mode 3	Mode 4
Toe	[ ]	[ ]	[ ]	[ ]
Lower bank	[ ]	[ ]	[ ]	[ ]
Upper bank	[ ]	[ ]	[ ]	[ ]
Whole bank	[ ]	[ ]	[ ]	[ ]

PART 12: LEFT BANK BERM CHARACTERISTICS

Present Status
- No berm [ ]
- small berm [ ]
- medium berm [X]
- large berm [ ]

Berm Location
- None [ ]
- Only inside bends [X]
- Continuous [ ]

Berm Material Size Data
- D50 (mm) [ ]
- sorting coefficient [ ]

Berm Materials
- Silt/clay [ ]
- Sand/silt/clay [ ]
- Sand/silt [ ]
- Sand [X]
- Sand/gravel [ ]
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders [ ]
- Bed rock [ ]

Berm Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [X]
- Reeds and sedges [ ]
- Shrubs [X]
- Saplings [X]
- Trees [X]

Age
- Imature [ ]
- Mature [X]
- Old [ ]

Berm Tree Types
- None [ ]
- Alder [ ]
- Ash [ ]
- Birch [ ]
- Cottonwood [ ]
- Elm [ ]
- Beech [ ]
- Sweet gum [ ]
- Willow [X]
- Other (specify) [ ]

Density
- None [ ]
- Sparce [ ]
- Medium [ ]
- Dense [X]

Diversity
- Mono-stand [ ]
- Mixed [ ]
- Climax-vegetation [X]

Spacing
- Continuous [ ]
- Close [X]
- Wide [ ]

Health
- Healthy [X]
- Unhealthy [ ]
- Dead [ ]

Height
- Short [ ]
- Medium [X]
- Tall [ ]

Roots
- Normal [X]
- Adventitious [ ]
- Exposed [ ]

Sub Reach 3

SECTION 2 - LEFT BANK SURVEY

PART 8: LEFT BANK CHARACTERISTICS

Type
- Noncohesive [X]
- Cohesive [ ]
- Composite [ ]
- Layered [ ]
- Even Layers [X]
- Thick+thin layers [ ]
- Number of layers [3]

Protection Status
- Unprotected [X]
- Hard points [ ]
- Revetments [ ]
- Dyke Fields [ ]

Bank Materials
- Silt/clay [ ]
- Sand/silt/clay [ ]
- Sand/silt [ ]
- Sand [X]
- Sand/gravel [ ]
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders/bedrock [ ]

Mean Bank Height
- Average height (ft) [15]

Mean Bank Slope
- Average angle (o) [25]-35°

Layer Thickness
- Material 1 (ft) [ ]
- Material 2 (ft) [ ]
- Material 3 (ft) [ ]
- Material 4 (ft) [ ]

Tension Cracks
- None [X]
- Occasional [ ]
- Frequent [ ]

Crack Extent
- Proportion of bank height [ ]

Distribution and Description of Bank Materials in Bank Profile

	Material Type 1	Material Type 2	Material Type 3	Material Type 4
Toe	[ ]	[ ]	[ ]	[ ]
Mid-Bnak	[ ]	[ ]	[ ]	[ ]
Upper Bank	[ ]	[ ]	[ ]	[ ]
Whole Bank	[ ]	[ ]	[ ]	[ ]
D50 (mm)	[ ]	[ ]	[ ]	[ ]
sorting coefficient	[ ]	[ ]	[ ]	[ ] (sorting coef.)

PART 9: LEFT BANK-FACE VEGETATION

Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [X]
- Reeds and sedges [ ]
- Shrubs [X]
- Saplings [X]
- Trees [X]

Tree Types
- None [ ]
- Alder [ ]
- Ash [ ]
- Beech [ ]
- Birch [ ]
- Cottonwood [ ]
- Elm [ ]
- Sweet gum [ ]
- Willow [X]

Density
- None [ ]
- Sparce [ ]
- Medium [ ]
- Dense [X]

Spacing
- Continuous [ ]
- Close [X]
- Wide [ ]

Location
- Whole bank [X]
- Bank top [ ]
- Mid-bank [ ]
- Bank toe [ ]

Diversity
- Mono-stand [ ]
- Mixed [ ]
- Climax-vegetation [X]

Health
- Healthy [X]
- Fair [ ]
- Poor [ ]
- Dead [ ]

Age
- Imature [ ]
- Mature [X]
- Old [ ]

Height
- Short [ ]
- Medium [X]
- Tall [ ]

Extent
- Wide [ ]
- Medium [ ]
- Narrow [ ]

PART 10: LEFT BANK EROSION PROCESSES

Status
- Intact [ ]
- Eroding [ ]
- Advancing [X]

Severity
- Insignificant [ ]
- Mild [X]
- Significant [ ]
- Serious [ ]
- Catastrophic [ ]

Extent
- Toe [X]
- Lower bank [X]
- Upper bank [ ]
- Whole bank [ ]

Estimated rate
- < 3ft/yr [X]
- 3 - 10 ft/yr [ ]
- 10 - 25 ft/yr [ ]
- >25 ft/yr [ ]

Location
- General [X]
- Outside Meander [ ]
- Inside Meander [ ]
- Opposite a bar [ ]
- Behind a bar [ ]
- Opposite a structure [ ]
- Adjacent to structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]
- Other [ ]

Processes
- Flow entrainment [ ]
- Piping [ ]
- Freeze/thaw [ ]
- Sheet erosion [ ]
- Rilling + gullying [ ]
- Wind waves [ ]
- Vessel Forces [ ]
- Ice rafting [ ]
- Aeolian [ ]
- Other [ ]

Distribution of Each Process on Bank

	Process 1	Process 2	Process 3	Process 4
Toe	[ ]	[ ]	[ ]	[ ]
Lower bank	[ ]	[ ]	[ ]	[ ]
Upper bank	[ ]	[ ]	[ ]	[ ]
Whole bank	[ ]	[ ]	[ ]	[ ]

PART 11: LEFT BANK FAILURE MECHANICS

Status
- Stable [X]
- Unreliable [ ]
- Unstable [ ]

Severity
- Insignificant [X]
- Moderate [ ]
- Serious [ ]

Extent
- Toe [ ]
- Lower bank [ ]
- Upper bank [ ]
- Whole bank [ ]

Frequency
- None [ ]
- Occasional [ ]
- Frequent [ ]

Location
- General [ ]
- Outside Meander [ ]
- Inside Meander [ ]
- Opposite a bar [ ]
- Behind a bar [ ]
- Opposite structure [ ]
- Adjacent structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]

Failure Mode
- Shallow slide [ ]
- Rotational slip [ ]
- Slab-type [ ]
- Pop-out failure [ ]
- Cantilever failure [ ]
- Piping [ ]
- Flow failure [ ]
- Ravelling [ ]

Distribution of Each Mode on Bank

	Mode 1	Mode 2	Mode 3	Mode 4
Toe	[ ]	[ ]	[ ]	[ ]
Lower bank	[ ]	[ ]	[ ]	[ ]
Upper bank	[ ]	[ ]	[ ]	[ ]
Whole bank	[ ]	[ ]	[ ]	[ ]

PART 12: LEFT BANK BERM CHARACTERISTICS

Present Status
- No berm [X]
- small berm [ ]
- medium berm [ ]
- large berm [ ]

Berm Location
- None [ ]
- Only inside bends [ ]
- Continuous [ ]

Berm Material Size Data
- D50 (mm) [ ]
- sorting coefficient [ ]

Berm Materials
- Silt/clay [ ]
- Sand/silt/clay [ ]
- Sand/silt [ ]
- Sand [ ]
- Sand/gravel [ ]
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders [ ]
- Bed rock [ ]

Berm Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [ ]
- Reeds and sedges [ ]
- Shrubs [ ]
- Saplings [ ]
- Trees [ ]

Age
- Imature [ ]
- Mature [ ]
- Old [ ]

Berm Tree Types
- None [ ]
- Alder [ ]
- Ash [ ]
- Birch [ ]
- Cottonwood [ ]
- Elm [ ]
- Beech [ ]
- Sweet gum [ ]
- Willow [ ]
- Other (specify) [ ]

Density
- None [ ]
- Sparce [ ]
- Medium [ ]
- Dense [ ]

Diversity
- Mono-stand [ ]
- Mixed [ ]
- Climax-vegetation [ ]

Spacing
- Continuous [ ]
- Close [ ]
- Wide [ ]

Health
- Healthy [ ]
- Unhealthy [ ]
- Dead [ ]

Height
- Short [ ]
- Medium [ ]
- Tall [ ]

Roots
- Normal [ ]
- Advantitious [ ]
- Exposed [ ]

Sub-reach 2

SECTION 2 - LEFT BANK SURVEY

PART 8: LEFT BANK CHARACTERISTICS

Type
- Noncohesive [ ]
- Cohesive [X]
- Composite [ ]
- Layered [ ]
- Even Layers [ ]
- Thick+thin layers [ ]
- Number of layers [ ]

Protection Status
- Unprotected [X]
- Hard points [ ]
- Revetments [ ]
- Dyke Fields [ ]

Bank Materials
- Silt/clay [X]
- Sand/silt/clay [ ]
- Sand/silt [ ]
- Sand [ ]
- Sand/gravel [ ]
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders/bedrock [ ]

Mean Bank Height
- Average height (ft) [15]

Mean Bank Slope
- Average angle (o) [75]

Layer Thickness
- Material 1 (ft) [ ]
- Material 2 (ft) [ ]
- Material 3 (ft) [ ]
- Material 4 (ft) [ ]

Tension Cracks
- None [ ]
- Occasional [X]
- Frequent [ ]

Crack Extent
- Proportion of bank height [10]%

Distribution and Description of Bank Materials in Bank Profile

	Material Type 1	Material Type 2	Material Type 3	Material Type 4
Toe	[ ]	[ ]	[ ]	[ ]
Mid-Bnak	[ ]	[ ]	[ ]	[ ]
Upper Bank	[ ]	[ ]	[ ]	[ ]
Whole Bank	[ ]	[ ]	[ ]	[ ]
D50 (mm)	[ ]	[ ]	[ ]	[ ]
sorting coefficient	[ ]	[ ]	[ ]	[ ]

PART 9: LEFT BANK-FACE VEGETATION

Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [X]
- Reeds and sedges [ ]
- Shrubs [ ]
- Saplings [ ]
- Trees [ ]

Tree Types
- None [X]
- Alder [ ]
- Ash [ ]
- Beech [ ]
- Birch [ ]
- Cottonwood [ ]
- Elm [ ]
- Sweet gum [ ]
- Willow [ ]

Density
- None [ ]
- Sparce [X]
- Medium [ ]
- Dense [ ]

Spacing
- Continuous [ ]
- Close [ ]
- Wide [X]

Location
- Whole bank [ ]
- Bank top [ ]
- Mid-bank [ ]
- Bank toe [X]

Diversity
- Mono-stand [ ]
- Mixed [ ]
- Climax-vegetation [ ]

Health
- Healthy [ ]
- Fair [ ]
- Poor [ ]
- Dead [ ]

Age
- Imature [ ]
- Mature [ ]
- Old [ ]

Height
- Short [ ]
- Medium [ ]
- Tall [ ]

Extent
- Wide [ ]
- Medium [ ]
- Narrow [ ]

PART 10: LEFT BANK EROSION PROCESSES

Status
- Intact [ ]
- Eroding [X]
- Advancing [ ]

Severity
- Insignificant [ ]
- Mild [ ]
- Significant [X]
- Serious [ ]
- C: astrophic [ ]

Extent
- Toe [ ]
- Lower bank [ ]
- Upper bank [ ]
- Whole bank [X]

Estimated rate
- < 3ft/yr [ ]
- 3 - 10 ft/yr [X]
- 10 - 25 ft/yr [ ]
- >25 ft/yr [ ]

Location
- General [ ]
- Outside Meander [X]
- Inside Meander [ ]
- Opposite a bar [X]
- Behind a bar [ ]
- Opposite a structure [ ]
- Adjacent to structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]
- Other [ ]

Processes
- Flow entrainment [ ]
- Piping [X]
- Freeze/thaw [ ]
- Sheet erosion [ ]
- Rilling + gullying [ ]
- Wind waves [ ]
- Vessel Forces [ ]
- Ice rafting [ ]
- Aeolian [ ]
- Other [ ]

Distribution of Each Process on Bank

	Process 1	Process 2	Process 3	Process 4
Toe	[ ]	[ ]	[ ]	[ ]
Lower bank	[ ]	[ ]	[ ]	[ ]
Upper bank	[ ]	[ ]	[ ]	[ ]
Whole bank	[ ]	[ ]	[ ]	[ ]

PART 11: LEFT BANK FAILURE MECHANICS

Status
- Stable [ ]
- Unreliable [ ]
- Unstable [X]

Severity
- Insignificant [ ]
- Moderate [X]
- Serious [ ]

Extent
- Toe [ ]
- Lower bank [ ]
- Upper bank [ ]
- Whole bank [X]

Frequency
- None [ ]
- Occasional [X]
- Frequent [ ]

Location
- General [ ]
- Outside Meander [X]
- Inside Meander [ ]
- Opposite a bar [X]
- Behind a bar [ ]
- Opposite structure [ ]
- Adjacent structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]

Failure Mode
- Shallow slide [ ]
- Rotational slip [ ]
- Slab-type [1]
- Pop-out failure [ ]
- Cantilever failure [ ]
- Piping [2]
- Flow failure [ ]
- Ravelling [ ]

Distribution of Each Mode on Bank

	Mode 1	Mode 2	Mode 3	Mode 4
Toe	[ ]	[ ]	[ ]	[ ]
Lower bank	[ ]	[ ]	[ ]	[ ]
Upper bank	[ ]	[ ]	[ ]	[ ]
Whole bank	[X]	[ ]	[ ]	[ ]

PART 12: LEFT BANK BERM CHARACTERISTICS

Present Status
- No berm [X]
- small berm [ ] ?
- medium berm [ ]
- large berm [ ]

Berm Location
- None [ ]
- Only inside bends [ ]
- Continuous [ ]

Berm Material Size Data
- D50 (mm) [ ]
- sorting coefficient [ ]

Berm Materials
- Silt/clay [ ]
- Sand/silt/clay [ ]
- Sand/silt [ ]
- Sand [ ]
- Sand/gravel [ ]
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders [ ]
- Bed rock [ ]

Berm Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [ ]
- Reeds and sedges [ ]
- Shrubs [ ]
- Saplings [ ]
- Trees [ ]

Age
- Imature [ ]
- Mature [ ]
- Old [ ]

Berm Tree Types
- None [ ]
- Alder [ ]
- Ash [ ]
- Birch [ ]
- Cottonwood [ ]
- Elm [ ]
- Beech [ ]
- Sweet gum [ ]
- Willow [ ]
- Other (specify) [ ]

Density
- None [ ]
- Sparce [ ]
- Medium [ ]
- Dense [ ]

Diversity
- Mono-stand [ ]
- Mixed [ ]
- Climax-vegetation [ ]

Spacing
- Continuous [ ]
- Close [ ]
- Wide [ ]

Health
- Healthy [ ]
- Unhealthy [ ]
- Dead [ ]

Height
- Short [ ]
- Medium [ ]
- Tall [ ]

Roots
- Normal [ ]
- Advantitious [ ]
- Exposed [ ]

Whole Reach

SECTION 3 - RIGHT BANK SURVEY

PART 13: RIGHT BANK CHARACTERISTICS

Type
- Noncohesive [X]
- Cohesive [ ]
- Composite [ ]
- Layered [ ]
- Even Layers [ ]
- Thick+thin layers [ ]
- Number of layers [ ]

Protection Status
- Unprotected [X]
- Hard points [ ]
- Revetments [ ]
- Dyke Fields [ ]

Bank Materials
- Silt/clay [ ]
- Sand/silt/clay [X] 2
- Sand/silt [ ]
- Sand [ ]
- Sand/gravel [X] 1
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders/bedrock [ ]

Wood board fence last sand bar at bridge

Mean Bank Height
- Average height (ft) [10]

Mean Bank Slope
- Average angle (o) [35]

Layer Thickness
- Material 1 (ft) [2]
- Material 2 (ft) [8]
- Material 3 (ft) [ ]
- Material 4 (ft) [ ]

Tension Cracks
- None [ ]
- Occasional [ ]
- Frequent [ ]

Crack Extent
- Proportion of bank height [ ]

Distribution and Description of Bank Materials in Bank Profile

	Material Type 1	Material Type 2	Material Type 3	Material Type 4
Toe	[X]	[ ]	[ ]	[ ]
Mid-Bank	[ ]	[X]	[ ]	[ ]
Upper Bank	[ ]	[X]	[ ]	[ ]
Whole Bank	[ ]	[ ]	[ ]	[ ]
D50 (mm)	[ ]	[ ]	[ ]	[ ]
sorting coefficient	[ ]	[ ]	[ ]	[ ]

PART 14: RIGHT BANK-FACE VEGETATION

Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [X]
- Reeds and sedges [ ]
- Shrubs [ ]
- Saplings [ ]
- Trees [X]

Tree Types
- None [ ]
- Alder [ ]
- Ash [ ]
- Beech [ ]
- Birch [ ]
- Cottonwood [ ]
- Elm [ ]
- Sweet gum [ ]
- Willow [X]

Density
- None [ ]
- Sparce [ ]
- Medium [X]
- Dense [ ]

Spacing
- Continuous [X]
- Close [ ]
- Wide [ ]

Location
- Whole bank [X]
- Bank top [ ]
- Mid-bank [ ]
- Bank toe [ ]

Diversity
- Mono-stand [ ]
- Mixed [X]
- Climax-vegetation [ ]

Health
- Healthy [ ]
- Fair [X]
- Poor [ ]
- Dead [ ]

Age
- Imature [X]
- Mature [ ]
- Old [ ]

Height
- Short [ ]
- Medium [X]
- Tall [ ]

Extent
- Wide [ ]
- Medium [ ]
- Narrow [X]

PART 15: RIGHT BANK EROSION PROCESSES

Status
- Intact [X]
- Eroding [ ]
- Advancing [X]

Severity
- Insignificant [X]
- Mild [ ]
- Significant [ ]
- Serious [ ]
- Catastrophic [ ]

Extent
- Toe [ ]
- Lower bank [ ]
- Upper bank [X]
- Whole bank [ ]

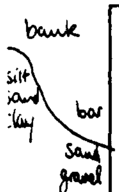
Estimated rate
- < 3ft/yr [X]
- 3 - 10 ft/yr [ ]
- 10 - 25 ft/yr [ ]
- >25 ft/yr [ ]

Location
- General [ ]
- Outside Meander [ ]
- Inside Meander [X]
- Opposite a bar [ ]
- Behind a bar [ ]
- Opposite a structure [ ]
- Adjacent to structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]
- Other [ ]

Processes
- Flow entrainment [X]
- Piping [ ]
- Freeze/thaw [ ]
- Sheet erosion [ ]
- Rilling + gullying [ ]
- Wind waves [ ]
- Vessel Forces [ ]
- Ice rafting [ ]
- Aeolian [ ]
- Other [ ]

Distribution of Each Process on Bank

	Process 1	Process 2	Process 3	Process 4
Toe	[ ]	[ ]	[ ]	[ ]
Lower bank	[ ]	[ ]	[ ]	[ ]
Upper bank	[X]	[ ]	[ ]	[ ]
Whole bank	[ ]	[ ]	[ ]	[ ]



PART 16: RIGHT BANK FAILURE MECHANICS

Status
- Stable [X]
- Unreliable [ ]
- Unstable [ ]

Severity
- Insignificant [X]
- Moderate [ ]
- Serious [ ]

Extent
- Toe [ ]
- Lower bank [ ]
- Upper bank [ ]
- Whole bank [ ]

Frequency
- None [ ]
- Occasional [X]
- Frequent [ ]

Location
- General [ ]
- Outside Meander [ ]
- Inside Meander [X]
- Opposite a bar [ ]
- Behind a bar [ ]
- Opposite structure [ ]
- Adjacent structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]

Failure Mode
- Shallow slide [X]
- Rotational slip [ ]
- Slab-type [ ]
- Pop-out failure [ ]
- Cantilever failure [ ]
- Piping [ ]
- Flow failure [ ]
- Ravelling [ ]

Distribution of Each Mode on Bank

	Mode 1	Mode 2	Mode 3	Mode 4
Toe	[ ]	[ ]	[ ]	[ ]
Lower bank	[ ]	[ ]	[ ]	[ ]
Upper bank	[X]	[ ]	[ ]	[ ]
Whole bank	[ ]	[ ]	[ ]	[ ]

PART 17: RIGHT BANK BERM CHARACTERISTICS

Present Status
- No berm [ ]
- small berm [ ]
- medium berm [X]
- large berm [ ]

Berm Location
- None [ ]
- Only inside bends [X]
- Continuous [ ]

Berm Material Size Data
- D50 (mm) [ ]
- sorting coefficient [ ]

Berm Materials
- Silt/clay [ ]
- Sand/silt/clay [ ]
- Sand/silt [ ]
- Sand [ ]
- Sand/gravel [X]
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders [ ]
- Bed rock [ ]

Berm Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [X]
- Reeds and sedges [ ]
- Shrubs [ ]
- Saplings [X]
- Trees [ ]

Age
- Imature [X]
- Mature [X]
- Old [ ]

Berm Tree Types
- None [ ]
- Alder [ ]
- Ash [ ]
- Birch [ ]
- Cottonwood [X]
- Elm [ ]
- Beech [ ]
- Sweet gum [ ]
- Willow [X]
- Other (specify) [ ]

Density
- None [ ]
- Sparce [X]
- Medium [ ]
- Dense [ ]

Diversity
- Mono-stand [X]
- Mixed [ ]
- Climax-vegetation [ ]

Spacing
- Continuous [ ]
- Close [X]
- Wide [ ]

Health
- Healthy [X]
- Unhealthy [ ]
- Dead [ ]

Height
- Short [X]
- Medium [ ]
- Tall [ ]

Roots
- Normal [X]
- Advantitious [ ]
- Exposed [ ]

SEDIMENTATION ANALYSIS SHEET
Developed by Colin R. Thorne
for the US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

RIVER *CLEAR CREEK* SITE *Bovina* REACH From *Farrah Bridge* To *Tiftontown Bridge*

SHEET COMPLETED BY *Groups 1, 2 + 3* DATE *10-18-90* TIME: START *2:10pm* TIME: FINISH *4:30pm*

SECTION 1 - VALLEY AND CHANNEL SURVEY

PART 1: AREA AROUND RIVER VALLEY

Terrain
- Mountains [ ]
- Uplands [ ]
- Hills [X]
- Plains [ ]
- Lowlands [ ]

Geology
- Bed rock [ ]
- Moraine [ ]
- Glacio/Fluvial [ ]
- Fluvial [X]
- Lacustrine [ ]
- Wind blown (loess) [X] *(Hills)*

Rock Type
- Cemented Clay [X]
- Shale [ ]
- Limestone [ ]
- Sandstone [ ]
- Conglomerate [ ]
- Granite [ ]

Land Use
- Natural [X] *Hills*
- Cultivated [X] *V.F.*
- Urban [ ]

Vegetation
- None [ ]
- Grass [X] *V.F.*
- Arable Crops [X]
- Shrubs [ ]
- Forest [X] *Hills*

V.F. = Valley Floor

Forest Type
- None [ ]
- Deciduous [X]
- Coniferous [ ]
- Mixed [ ]

PART 2: VALLEY SIDES

Height
- < 20 feet [ ]
- 20-50 feet [X]
- 50-100 feet [ ]
- >100 feet [ ]

Side Slope Angle
- < 30 degrees [ ]
- 30-60 degrees [X] *(45-50°)*
- >60 degrees [ ]

Valley side Failures
- None [ ]
- Occasional [X]
- Frequent [ ]

Severity of Problems
- Insignificant [X]
- Moderate [ ]
- Serious [ ]

Failure Locations
- None [ ]
- Away from river [X]
- Along river (Undercut) [ ]

Failure Types
- None [ ]
- Shallow slide [ ]
- Rotational slip [ ]
- Slab-type [X]
- Piping [ ]
- Flow failure [ ]

PART 3: VERTICAL RELATION OF CHANNEL TO VALLEY

Present status
- Adjusted [ ]
- Incised [X]
- Aggraded [ ]

Instability:Status
- Insignificant [ ]
- Moderate [X]
- Serious [ ]

Instability:extent
- None [ ]
- Local [X]
- General [ ]
- Reach scale [ ]
- System wide [ ]
- Regional scale [ ]

Terraces
- None [ ]
- Indefinate [ ]
- Fragmentary [ ]
- Continuous [ ]
- Number of terraces [X]

Number of Terraces
- Number above valley Floor [1]

Overbank Deposits
- None [ ]
- Silt [ ]
- Fine sand [ ]
- Medium sand [X]
- Coarse sand [ ]
- Gravel [ ]

Levees
- None [X]
- Indefinate [ ]
- Fragmentary [ ]
- Continuous [ ]

Levee Type
- Natural [ ]
- Man-made [ ]

Levee Data
- Height (f) [ ]
- Side Slope (o) [ ]

Levee Failures
- None [ ]
- Occasional [ ]
- Frequent [ ]

PART 4: LATERAL RELATION OF CHANNEL TO VALLEY

Present Status
- Adjusted [X]
- over wide [ ]
- narrow [ ]

Instability:Status
- Insignificant [ ]
- Moderate [X]
- Serious [ ]

Instability:extent
- None [ ]
- Local [X]
- General [ ]
- Reach scale [ ]
- System wide [ ]
- Regional scale [ ]

Planform
- Straight [ ]
- Sinuous [ ]
- Irregular [ ]
- Regular meanders [ ]
- Irregular meanders [X]
- Tortuous meanders [ ]
- Braided [ ]

Planform Data
- Bend Radius [ ]
- Meander belt width [ ]
- Wavelength [ ]
- Meander Sinuosity [ ]

Valley Floor Type
- None [ ]
- Indefinate [ ]
- Fragmentary [ ]
- Continuous [X]

Valley Floor Data
- < 1 river width [ ]
- 1 - 5 river widths [ ]
- > 5 river widths [X]

Note:
width = channel top width

PART 5: CHANNEL DESCRIPTION

Dimensions
- Ave. top bank width [80-] *100 ft*
- Ave. channel depth [20]
- Ave. water width [20]
- Ave. water depth [1-] *2 ft*
- Reach slope [?]
- Mean velocity [1-] *3 ft/s*
- Manning's n value [0.] *035*

Flow Type
- None [ ]
- Uniform/Tranquil [ ]
- Uniform/Rapid [ ]
- Pool+Riffle [X]
- Tumbling [ ]
- Step-pool [ ]

Bed Controls
- None [ ]
- Occasional [X]
- Frequent [ ]
- Confined [ ]
- Number of controls [ ]

Control Types
- None [ ]
- Bedrock [ ]
- Boulders [ ]
- Gravel armor [ ]
- Bridge aprons [X]
- Grade control structures [ ]

Width Controls
- None [ ]
- Occasional [X]
- Frequent [ ]
- Confined [ ]
- Number of controls [ ]

Control Types
- None [ ]
- Bedrock [ ]
- Boulders [ ]
- Gravel armor [ ]
- Revetments [X]
- Bridge abutments [X]
- dykes or groynes [ ]

PART 7: BED SEDIMENT DESCRIPTION

Bed Material
- Silt [ ]
- Sand [ ]
- Sand and gravel [X]
- gravel and cobbles [ ]
- cobbles + boulders [ ]
- boulders + bedrock [ ]
- Bed rock [ ]

Bed Armour
- None [ ]
- Static-armour [X]
- Mobile-armour [ ]

Sediment Depth
- Depth of loose Sediment in bed (ft) [?]

Surface Size Data
- D50 (mm) [ ]
- D84 (mm) [ ]
- sorting coefficient [ ]

Substrate Size Data
- D50 (mm) [ ]
- D84 (mm) [ ]
- sorting coefficient [ ]

Bed Forms
- Plane bed [X]
- Ripples [ ]
- Dunes [ ]
- Bed form height (ft) [ ]

Island or Bars
- None [ ]
- Occasional [X]
- Frequent [ ]

Bar Types
- None [ ]
- Pools and riffles [X]
- Alternate bars [X]
- Point bars [X]
- Mid-channel bars [X]
- Diagonal bars [ ]
- Sand waves + dunes [ ]

Bar Surface data
- D50 (mm) [ ]
- D84 (mm) [ ]
- sorting coef. [ ]

Bar Substrate data
- D50 (mm) [ ]
- D84 (mm) [ ]
- sorting coef. [ ]

Sub-REACH 1 – 1st Bend

SECTION 2 - LEFT BANK SURVEY

PART 8: LEFT BANK CHARACTERISTICS

Type
- Noncohesive [X]
- Cohesive [ ]
- Composite [ ]
- Layered [ ]
- Even Layers [ ]
- Thick+thin layers [ ]
- Number of layers [ ]

Protection Status
- Unprotected [X]
- Hard points [ ]
- Revetments [ ]
- Dyke Fields [ ]

Bank Materials
- Silt/clay [ ]
- Sand/silt/clay [ ]
- Sand/silt [ ]
- Sand [X]
- Sand/gravel [ ]
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders/bedrock [ ]

Mean Bank Height
- Average height (ft) [8] -10

Mean Bank Slope
- Average angle (o) [30]

Layer Thickness
- Material 1 (ft) [8]
- Material 2 (ft) [ ]
- Material 3 (ft) [ ]
- Material 4 (ft) [ ]

Tension Cracks
- None [X]
- Occasional [ ]
- Frequent [ ]

Crack Extent
- Proportion of bank height [ ]

Distribution and Description of Bank Materials in Bank Profile

	Material Type 1	Material Type 2	Material Type 3	Material Type 4
Toe	[ ]	[ ]	[ ]	[ ]
Mid-Bnak	[ ]	[ ]	[ ]	[ ]
Upper Bank	[ ]	[ ]	[ ]	[ ]
Whole Bank	[X]	[ ]	[ ]	[ ]
D50 (mm)	[ ]	[ ]	[ ]	[ ]
sorting coefficient	[ ]	[ ]	[ ]	[ ]

PART 9: LEFT BANK-FACE VEGETATION

Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [X] on Bank
- Reeds and sedges [ ]
- Shrubs [ ]
- Saplings [X] on Bank
- Trees [X]

Overbank

Tree Types
- None [ ]
- Alder [ ]
- Ash [ ]
- Beech [ ]
- Birch [ ]
- Cottonwood [ ]
- Elm [ ]
- Sweet gum [ ]
- Willow [X] 30 ft tall on overbank

Density
- None [ ]
- Sparce [ ]
- Medium [X]
- Dense [ ]

Spacing
- Continuous [X]
- Close [ ]
- Wide [ ]

Location
- Whole bank [X]
- Bank top [X] and over
- Mid-bank [ ]
- Bank toe [ ]

Diversity
- Mono-stand [ ]
- Mixed [X]
- Climax-vegetation [ ]

Health
- Healthy [X]
- Fair [ ]
- Poor [ ]
- Dead [ ]

Age
- Imature [X]
- Mature [X]
- Old [ ]

Height
- Short [ ]
- Medium [X]
- Tall [ ]

Extent
- Wide [ ]
- Medium [X]
- Narrow [ ]

PART 10: LEFT BANK EROSION PROCESSES

Status
- Intact [ ]
- Eroding [ ]
- Advancing [X]

Severity
- Insignificant [ ]
- Mild [ ]
- Significant [X]
- Serious [ ]
- Catastrophic [ ]

Extent
- Toe [ ]
- Lower bank [X]
- Upper bank [ ]
- Whole bank [ ]

Estimated rate
- < 3ft/yr [ ]
- 3 - 10 ft/yr [ ]
- 10 - 25 ft/yr [ ]
- >25 ft/yr [ ]

Location
- General [ ]
- Outside Meander [ ]
- Inside Meander [X]
- Opposite a bar [ ]
- Behind a bar [X]
- Opposite a structure [ ]
- Adjacent to structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]
- Other [ ]

Processes
- Flow entrainment [X]
- Piping [ ]
- Freeze/thaw [ ]
- Sheet erosion [ ]
- Rilling + gullying [ ]
- Wind waves [ ]
- Vessel Forces [ ]
- Ice rafting [ ]
- Aeolian [ ]
- Other [ ]

Distribution of Each Process on Bank

	Process 1	Process 2	Process 3	Process 4
Toe	[X]	[ ]	[ ]	[ ]
Lower bank	[X]	[ ]	[ ]	[ ]
Upper bank	[ ]	[ ]	[ ]	[ ]
Whole bank	[ ]	[ ]	[ ]	[ ]

PART 11: LEFT BANK FAILURE MECHANICS

Status
- Stable [X]
- Unreliable [ ]
- Unstable [ ]

Severity
- Insignificant [X]
- Moderate [ ]
- Serious [ ]

Extent
- Toe [ ]
- Lower bank [ ]
- Upper bank [ ]
- Whole bank [X]

Frequency
- None [X]
- Occasional [ ]
- Frequent [ ]

Location
- General [ ]
- Outside Meander [ ]
- Inside Meander [X]
- Opposite a bar [ ]
- Behind a bar [ ]
- Opposite structure [ ]
- Adjacent structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]

Failure Mode
- Shallow slide [ ]
- Rotational slip [ ]
- Slab-type [ ]
- Pop-out failure [ ]
- Cantilever failure [ ]
- Piping [ ]
- Flow failure [ ]
- Ravelling [ ]

Distribution of Each Mode on Bank

	Mode 1	Mode 2	Mode 3	Mode 4
Toe	[ ]	[ ]	[ ]	[ ]
Lower bank	[ ]	[ ]	[ ]	[ ]
Upper bank	[ ]	[ ]	[ ]	[ ]
Whole bank	[ ]	[ ]	[ ]	[ ]

PART 12: LEFT BANK BERM CHARACTERISTICS

Present Status
- No berm [ ]
- small berm [ ]
- medium berm [X]
- large berm [ ]

Berm Location
- None [ ]
- Only inside bends [X]
- Continuous [ ]

Berm Material Size Data
- D50 (mm) [ ]
- sorting coefficient [ ]

Berm Materials
- Silt/clay [ ]
- Sand/silt/clay [ ]
- Sand/silt [ ]
- Sand [X]
- Sand/gravel [ ]
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders [ ]
- Bed rock [ ]

Berm Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [X]
- Reeds and sedges [ ]
- Shrubs [ ]
- Saplings [X]
- Trees [ ]

Age Tree
- Imature [X]
- Mature [X] Grass
- Old [ ]

Berm Tree Types
- None [ ]
- Alder [ ]
- Ash [ ]
- Birch [ ]
- Cottonwood [ ]
- Elm [ ]
- Beech [ ]
- Sweet gum [ ]
- Willow [X]
- Other (specify) [ ]

Density
- None [ ]
- Sparce [ ]
- Medium [X]
- Dense [ ]

Diversity
- Mono-stand [ ]
- Mixed [X]
- Climax-vegetation [ ]

Spacing
- Continuous [X] Grass
- Close [X] Tree
- Wide [ ]

Health
- Healthy [X]
- Unhealthy [ ]
- Dead [ ]

Height
- Short [ ]
- Medium [X]
- Tall [ ]

Roots
- Normal [X]
- Advantitious [ ]
- Exposed [ ]

REACH 2 - 2nd Bend

SECTION 2 - LEFT BANK SURVEY

PART 8: LEFT BANK CHARACTERISTICS

Type
- Noncohesive [X]
- Cohesive [ ]
- Composite [ ]
- Layered [ ]
- Even Layers [ ]
- Thick+thin layers [ ]
- Number of layers [ ]

Protection Status
- Unprotected [X]
- Hard points [ ]
- Revetments [ ]
- Dyke Fields [ ]

Bank Materials
- Silt/clay [ ]
- Sand/silt/clay [ ]
- Sand/silt [ ]
- Sand [1]
- Sand/gravel [ ]
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders/bedrock [ ]

Mean Bank Height
- Average height (ft) [ ] 15-20ft

Mean Bank Slope
- Average angle (o) [90]

Layer Thickness
- Material 1 (ft) [15-20ft]
- Material 2 (ft) [ ]
- Material 3 (ft) [ ]
- Material 4 (ft) [ ]

Tension Cracks
- None [X]
- Occasional [ ]
- Frequent [ ]

Crack Extent
- Proportion of bank height [ ]

Distribution and Description of Bank Materials in Bank Profile

	Material Type 1	Material Type 2	Material Type 3	Material Type 4
Toe	[ ]	[ ]	[ ]	[ ]
Mid-Bnak	[ ]	[ ]	[ ]	[ ]
Upper Bank	[ ]	[ ]	[ ]	[ ]
Whole Bank	[X]	[ ]	[ ]	[ ]
D50 (mm)	[ ]	[ ]	[ ]	[ ]
sorting coefficient	[ ]	[ ]	[ ]	[ ]

PART 9: LEFT BANK-FACE VEGETATION

Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [X]
- Reeds and sedges [ ]
- Shrubs [ ]
- Saplings [ ]
- Trees [ ]

Tree Types
- None [X]
- Alder [ ]
- Ash [ ]
- Beech [ ]
- Birch [ ]
- Cottonwood [ ]
- Elm [ ]
- Sweet gum [ ]
- Willow [ ]

Density
- None [ ]
- Sparce [ ]
- Medium [ ]
- Dense [ ]

Spacing
- Continuous [ ]
- Close [ ]
- Wide [X]

Location
- Whole bank [ ]
- Bank top [ ]
- Mid-bank [ ]
- Bank toe [X]

Diversity
- Mono-stand [ ]
- Mixed [X]
- Climax-vegetation [ ]

Health
- Healthy [ ]
- Fair [X]
- Poor [ ]
- Dead [ ]

Age
- Imature [ ]
- Mature [ ]
- Old [ ]

Height
- Short [ ]
- Medium [ ]
- Tall [ ]

Extent
- Wide [ ]
- Medium [ ]
- Narrow [ ]

PART 10: LEFT BANK EROSION PROCESSES

Status
- Intact [ ]
- Eroding [X]
- Advancing [ ]

Severity
- Insignificant [ ]
- Mild [ ]
- Significant [ ]
- Serious [X]
- Catastrophic [ ]

Extent
- Toe [ ]
- Lower bank [ ]
- Upper bank [ ]
- Whole bank [X]

Estimated rate
- < 3ft/yr [ ]
- 3 - 10 ft/yr [ ]
- 10 - 25 ft/yr [ ]
- >25 ft/yr [ ]

Location
- General [ ]
- Outside Meander [X]
- Inside Meander [ ]
- Opposite a bar [X]
- Behind a bar [ ]
- Opposite a structure [ ]
- Adjacent to structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]
- Other [ ]

Processes
- Flow entrainment [1]
- Piping [2]
- Freeze/thaw [ ]
- Sheet erosion [ ]
- Rilling + gullying [ ]
- Wind waves [ ]
- Vessel Forces [ ]
- Ice rafting [ ]
- Aeolian [ ]
- Other [ ]

Distribution of Each Process on Bank

	Process 1	Process 2	Process 3	Process 4
Toe	[ ]	[ ]	[ ]	[ ]
Lower bank	[ ]	[X]	[ ]	[ ]
Upper bank	[ ]	[ ]	[ ]	[ ]
Whole bank	[X]	[ ]	[ ]	[ ]

PART 11: LEFT BANK FAILURE MECHANICS

Status
- Stable [ ]
- Unreliable [ ]
- Unstable [X]

Severity
- Insignificant [ ]
- Moderate [ ]
- Serious [X]

Extent
- Toe [ ]
- Lower bank [ ]
- Upper bank [ ]
- Whole bank [X]

Frequency
- None [ ]
- Occasional [ ]
- Frequent [ ]

Location
- General [ ]
- Outside Meander [X]
- Inside Meander [ ]
- Opposite a bar [ ]
- Behind a bar [ ]
- Opposite structure [ ]
- Adjacent structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]

Failure Mode
- Shallow slide [1]
- Rotational slip [ ]
- Slab-type [2]
- Pop-out failure [ ]
- Cantilever failure [ ]
- Piping [3]
- Flow failure [ ]
- Ravelling [ ]

Distribution of Each Mode on Bank

	Mode 1	Mode 2	Mode 3	Mode 4
Toe	[ ]	[ ]	[ ]	[ ]
Lower bank	[ ]	[ ]	[ ]	[ ]
Upper bank	[ ]	[ ]	[ ]	[ ]
Whole bank	[X]	[X]	[X]	[ ]

PART 12: LEFT BANK BERM CHARACTERISTICS

Present Status
- No berm [X]
- small berm [ ]
- medium berm [ ]
- large berm [ ]

Berm Location
- None [X]
- Only inside bends [ ]
- Continuous [ ]

Berm Material Size Data
- D50 (mm) [ ]
- sorting coefficient [ ]

Berm Materials
- Silt/clay [ ]
- Sand/silt/clay [ ]
- Sand/silt [ ]
- Sand [ ]
- Sand/gravel [ ]
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders [ ]
- Bed rock [ ]

Berm Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [ ]
- Reeds and sedges [ ]
- Shrubs [ ]
- Saplings [ ]
- Trees [ ]

Age
- Imature [ ]
- Mature [ ]
- Old [ ]

Berm Tree Types
- None [ ]
- Alder [ ]
- Ash [ ]
- Birch [ ]
- Cottonwood [ ]
- Elm [ ]
- Beech [ ]
- Sweet gum [ ]
- Willow [ ]
- Other (specify) [ ]

Density
- None [ ]
- Sparce [ ]
- Medium [ ]
- Dense [ ]

Diversity
- Mono-stand [ ]
- Mixed [ ]
- Climax-vegetation [ ]

Spacing
- Continuous [ ]
- Close [ ]
- Wide [ ]

Health
- Healthy [ ]
- Unhealthy [ ]
- Dead [ ]

Height
- Short [ ]
- Medium [ ]
- Tall [ ]

Roots
- Normal [ ]
- Adventitious [ ]
- Exposed [ ]

REACH 3 - Straight Reach to Bridge

SECTION 2 - LEFT BANK SURVEY

PART 8: LEFT BANK CHARACTERISTICS

Type
- Noncohesive [X]
- Cohesive [ ]
- Composite [ ]
- Layered [ ]
- Even Layers [ ]
- Thick+thin layers [ ]
- Number of layers [ ]

Protection Status
- Unprotected [X]
- Hard points [ ]
- Revetments [ ]
- Dyke Fields [ ]

Bank Materials
- Silt/clay [ ]
- Sand/silt/clay [ ]
- Sand/silt [ ]
- Sand [\]
- Sand/gravel [2]
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders/bedrock [ ]

Mean Bank Height
- Average height (ft) [ ] 3-6 ft

Mean Bank Slope
- Average angle (o) [30]

Layer Thickness
- Material 1 (ft) [1]
- Material 2 (ft) [2]
- Material 3 (ft) [ ]
- Material 4 (ft) [ ]

Tension Cracks
- None [X]
- Occasional [ ]
- Frequent [ ]

Crack Extent
- Proportion of bank height [ ]

Distribution and Description of Bank Materials in Bank Profile

	Material Type 1	Material Type 2	Material Type 3	Material Type 4
Toe	[ ]	[ ]	[ ]	[ ]
Mid-Bank	[X]	[X]	[ ]	[ ]
Upper Bank	[ ]	[ ]	[ ]	[ ]
Whole Bank	[ ]	[ ]	[ ]	[ ]
D50 (mm)	[ ]	[ ]	[ ]	[ ]
sorting coefficient	[ ]	[ ]	[ ]	[ ]

PART 9: LEFT BANK-FACE VEGETATION

Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [X]
- Reeds and sedges [ ]
- Shrubs [ ]
- Saplings [ ]
- Trees [ ]

Tree Types
- None [ ]
- Alder [ ]
- Ash [ ]
- Beech [ ]
- Birch [ ]
- Cottonwood [ ]
- Elm [ ]
- Sweet gum [ ]
- Willow [X]

Density
- None [ ]
- Sparce [ ]
- Medium [X]
- Dense [ ]

Spacing
- Continuous [X]
- Close [ ]
- Wide [ ]

Location
- Whole bank [X]
- Bank top [ ]
- Mid-bank [ ]
- Bank toe [ ]

Diversity
- Mono-stand [ ]
- Mixed [X]
- Climax-vegetation [ ]

Health
- Healthy [X]
- Fair [ ]
- Poor [ ]
- Dead [ ]

Age
- Imature [ ]
- Mature [ ]
- Old [ ]

Height
- Short [ ]
- Medium [X]
- Tall [ ]

Extent
- Wide [X]
- Medium [ ]
- Narrow [ ]

PART 10: LEFT BANK EROSION PROCESSES

Status
- Intact [ ]
- Eroding [X] Outside Bends
- Advancing [X] Inside Bends

Severity
- Insignificant [ ]
- Mild [X]
- Significant [ ]
- Serious [ ]
- Catastrophic [ ]

Extent
- Toe [ ]
- Lower bank [ ]
- Upper bank [ ]
- Whole bank [X]

Estimated rate
- < 3ft/yr [ ]
- 3 - 10 ft/yr [ ]
- 10 - 25 ft/yr [ ]
- >25 ft/yr [ ]

Location
- General [ ]
- Outside Meander [X]
- Inside Meander [X]
- Opposite a bar [X]
- Behind a bar [X]
- Opposite a structure [ ]
- Adjacent to structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]
- Other [ ]

Processes
- Flow entrainment [/]
- Piping [ ]
- Freeze/thaw [ ]
- Sheet erosion [ ]
- Rilling + gullying [ ]
- Wind waves [ ]
- Vessel Forces [ ]
- Ice rafting [ ]
- Aeolian [ ]
- Other [ ]

Distribution of Each Process on Bank

	Process 1	Process 2	Process 3	Process 4
Toe	[ ]	[ ]	[ ]	[ ]
Lower bank	[ ]	[ ]	[ ]	[ ]
Upper bank	[ ]	[ ]	[ ]	[ ]
Whole bank	[X]	[ ]	[ ]	[ ]

PART 11: LEFT BANK FAILURE MECHANICS

Status
- Stable [X] INSIDE
- Unreliable [X] OUTSIDE
- Unstable [ ]

Severity
- Insignificant [X] Both
- Moderate [ ]
- Serious [ ]

Extent
- Toe [ ]
- Lower bank [ ]
- Upper bank [ ]
- Whole bank [X]

Frequency
- None [ ]
- Occasional [ ]
- Frequent [ ]

Location
- General [ ]
- Outside Meander [X]
- Inside Meander [X]
- Opposite a bar [X]
- Behind a bar [X]
- Opposite structure [ ]
- Adjacent structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]

Failure Mode
- Shallow slide [ ]
- Rotational slip [ ]
- Slab-type [ ]
- Pop-out failure [ ]
- Cantilever failure [ ]
- Piping [ ]
- Flow failure [ ]
- Ravelling [X] outside Bends

Distribution of Each Mode on Bank

	Mode 1	Mode 2	Mode 3	Mode 4
Toe	[ ]	[ ]	[ ]	[ ]
Lower bank	[ ]	[ ]	[ ]	[ ]
Upper bank	[ ]	[ ]	[ ]	[ ]
Whole bank	[X]	[ ]	[ ]	[ ]

PART 12: LEFT BANK BERM CHARACTERISTICS

Present Status
- No berm [ ]
- small berm [X]
- medium berm [ ]
- large berm [ ]

Berm Location
- None [ ]
- Only inside bends [X]
- Continuous [ ]

Berm Material Size Data
- D50 (mm) [ ]
- sorting coefficient [ ]

Berm Materials
- Silt/clay [ ]
- Sand/silt/clay [ ]
- Sand/silt [ ]
- Sand [ ]
- Sand/gravel [X]
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders [ ]
- Bed rock [ ]

Berm Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [X]
- Reeds and sedges [ ]
- Shrubs [ ]
- Saplings [X]
- Trees [ ]

Age
- Imature [X]
- Mature [ ]
- Old [ ]

Berm Tree Types
- None [ ]
- Alder [ ]
- Ash [ ]
- Birch [ ]
- Cottonwood [ ]
- Elm [ ]
- Beech [ ]
- Sweet gum [ ]
- Willow [X]
- Other (specify) [ ]

Density
- None [ ]
- Sparce [ ]
- Medium [X]
- Dense [ ]

Diversity
- Mono-stand [ ]
- Mixed [X]
- Climax-vegetation [ ]

Spacing
- Continuous [X]
- Close [ ]
- Wide [ ]

Health
- Healthy [X]
- Unhealthy [ ]
- Dead [ ]

Height
- Short [ ]
- Medium [X]
- Tall [ ]

Roots
- Normal [X]
- Advantitious [ ]
- Exposed [ ]

Sub-Reach 1 and 2 – Bend and Straight Reach

SECTION 3 - RIGHT BANK SURVEY

PART 13: RIGHT BANK CHARACTERISTICS

Type
- Noncohesive [ ]
- Cohesive [X]
- Composite [ ]
- Layered [ ]
- Even Layers [ ]
- Thick+thin layers [X]
- Number of layers [3]

Protection Status
- Unprotected [ ]
- Hard points [ ]
- Revetments [X]
- Dyke Fields [ ]

Bank Materials
- Silt/clay [X]
- Sand/silt/clay [ ]
- Sand/silt [ ]
- Sand [ ]
- Sand/gravel [X]
- Gravel [X]
- Gravel/cobbles [X]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders/bedrock [ ]

Mean Bank Height
- Average height (ft) [15] 20 ft

Mean Bank Slope
- Average angle (o) [40] 60°

Layer Thickness
- Material 1 (ft) [ ]
- Material 2 (ft) [ ]
- Material 3 (ft) [ ]
- Material 4 (ft) [ ]

Tension Cracks
- None [X]
- Occasional [ ]
- Frequent [ ]

Crack Extent
- Proportion of bank height [ ]

Distribution and Description of Bank Materials in Bank Profile

	Material Type 1	Material Type 2	Material Type 3	Material Type 4
Toe	[X]	[ ]	[ ]	[ ]
Mid-Bnak	[ ]	[X]	[ ]	[ ]
Upper Bank	[ ]	[ ]	[X]	[ ]
Whole Bank	[ ]	[ ]	[ ]	[ ]
D50 (mm)	[ ]	[ ]	[ ]	[ ]
sorting coefficient	[ ]	[ ]	[ ]	[ ] (sorting coef.)

PART 14: RIGHT BANK-FACE VEGETATION

Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [X]
- Reeds and sedges [X]
- Shrubs [X]
- Saplings [X]
- Trees [X]

Tree Types
- None [ ]
- Alder [ ]
- Ash [X]
- Beech [ ]
- Birch [ ]
- Cottonwood [X]
- Elm [ ]
- Sweet gum [ ]
- Willow [X]

Density
- None [ ]
- Sparce [ ]
- Medium [ ]
- Dense [X]

Spacing
- Continuous [ ]
- Close [X]
- Wide [ ]

Location
- Whole bank [X]
- Bank top [ ]
- Mid-bank [ ]
- Bank toe [ ]

Diversity
- Mono-stand [ ]
- Mixed [X]
- Climax-vegetation [ ]

Health
- Healthy [X]
- Fair [ ]
- Poor [ ]
- Dead [ ]

Age
- Imature [X]
- Mature [ ]
- Old [ ]

Height
- Short [ ]
- Medium [X]
- Tall [ ]

Extent
- Wide [ ]
- Medium [X]
- Narrow [ ]

PART 15: RIGHT BANK EROSION PROCESSES

Status
- Intact [X]
- Eroding [ ]
- Advancing [ ]

Severity
- Insignificant [ ]
- Mild [X]
- Significant [ ]
- Serious [ ]
- Catastrophic [ ]

Extent
- Toe [X]
- Lower bank [ ]
- Upper bank [ ]
- Whole bank [ ]

Estimated rate
- < 3ft/yr [ ]
- 3 - 10 ft/yr [ ]
- 10 - 25 ft/yr [ ]
- >25 ft/yr [ ]

Location
- General [ ]
- Outside Meander [ ]
- Inside Meander [ ]
- Opposite a bar [X]
- Behind a bar [ ]
- Opposite a structure [ ]
- Adjacent to structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]
- Other [ ]

Processes
- Flow entrainment [1]
- Piping [ ]
- Freeze/thaw [ ]
- Sheet erosion [ ]
- Rilling + gullying [2]
- Wind waves [ ]
- Vessel Forces [ ]
- Ice rafting [ ]
- Aeolian [ ]
- Other [ ]

Distribution of Each Process on Bank

	Process 1	Process 2	Process 3	Process 4
Toe	[X] /	[ ]	[ ]	[ ]
Lower bank	[ ]	[ ]	[ ]	[ ]
Upper bank	[ ]	[X]	[ ]	[ ]
Whole bank	[ ]	[ ]	[ ]	[ ]

PART 16: RIGHT BANK FAILURE MECHANICS

Status
- Stable [ ]
- Unreliable [X]
- Unstable [ ]

Severity
- Insignificant [ ]
- Moderate [X]
- Serious [ ]

Extent
- Toe [ ]
- Lower bank [ ]
- Upper bank [X]
- Whole bank [ ]

Frequency
- None [ ]
- Occasional [X]
- Frequent [ ]

Location
- General [ ]
- Outside Meander [ ]
- Inside Meander [ ]
- Opposite a bar [X]
- Behind a bar [ ]
- Opposite structure [ ]
- Adjacent structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]

Failure Mode
- Shallow slide [1]
- Rotational slip [ ]
- Slab-type [2]
- Pop-out failure [ ]
- Cantilever failure [3]
- Piping [ ]
- Flow failure [ ]
- Ravelling [ ]

Distribution of Each Mode on Bank

	Mode 1	Mode 2	Mode 3	Mode 4
Toe	[ ]	[ ]	[ ]	[ ]
Lower bank	[ ]	[ ]	[ ]	[ ]
Upper bank	[X]	[X]	[X]	[ ]
Whole bank	[ ]	[ ]	[ ]	[ ]

PART 17: RIGHT BANK BERM CHARACTERISTICS

Present Status
- No berm [X]
- small berm [ ]
- medium berm [ ]
- large berm [ ]

Berm Location
- None [ ]
- Only inside bends [ ]
- Continuous [ ]

Berm Material Size Data
- D50 (mm) [ ]
- sorting coefficient [ ]

Berm Materials
- Silt/clay [ ]
- Sand/silt/clay [ ]
- Sand/silt [ ]
- Sand [ ]
- Sand/gravel [ ]
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders [ ]
- Bed rock [ ]

Berm Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [ ]
- Reeds and sedges [ ]
- Shrubs [ ]
- Saplings [ ]
- Trees [ ]

Age
- Imature [ ]
- Mature [ ]
- Old [ ]

Berm Tree Types
- None [ ]
- Alder [ ]
- Ash [ ]
- Birch [ ]
- Cottonwood [ ]
- Elm [ ]
- Beech [ ]
- Sweet gum [ ]
- Willow [ ]
- Other (specify) [ ]

Density
- None [ ]
- Sparce [ ]
- Medium [ ]
- Dense [ ]

Diversity
- Mono-stand [ ]
- Mixed [ ]
- Climax-vegetation [ ]

Spacing
- Continuous [ ]
- Close [ ]
- Wide [ ]

Health
- Healthy [ ]
- Unhealthy [ ]
- Dead [ ]

Height
- Short [ ]
- Medium [ ]
- Tall [ ]

Roots
- Normal [ ]
- Adventitious [ ]
- Exposed [ ]

Reach 2 - 2nd Bend

SECTION 3 - RIGHT BANK SURVEY

PART 13: RIGHT BANK CHARACTERISTICS

Type
- Noncohesive [ ]
- Cohesive [X]
- Composite [ ]
- Layered [ ]
- Even Layers [ ]
- Thick+thin layers [ ]
- Number of layers [ ]

Protection Status
- Unprotected [X]
- Hard points [ ]
- Revetments [ ]
- Dyke Fields [ ]

Bank Materials
- Silt/clay [X]
- Sand/silt/clay [ ]
- Sand/silt [ ]
- Sand [ ]
- Sand/gravel [ ]
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders/bedrock [ ]

Mean Bank Height
- Average height (ft) [5]

Mean Bank Slope
- Average angle (o) [40]

Layer Thickness
- Material 1 (ft) [ ]
- Material 2 (ft) [ ]
- Material 3 (ft) [ ]
- Material 4 (ft) [ ]

Tension Cracks
- None [ ]
- Occasional [ ]
- Frequent [ ]

Crack Extent
- Proportion of bank height [ ]

Distribution and Description of Bank Materials in Bank Profile

	Material Type 1	Material Type 2	Material Type 3	Material Type 4
Toe	[ ]	[ ]	[ ]	[ ]
Mid-Bnak	[ ]	[ ]	[ ]	[ ]
Upper Bank	[ ]	[ ]	[ ]	[ ]
Whole Bank	[ ]	[ ]	[ ]	[ ]
D50 (mm)	[ ]	[ ]	[ ]	[ ]
sorting coefficient (sorting coef.)	[ ]	[ ]	[ ]	[ ]

PART 14: RIGHT BANK-FACE VEGETATION

Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [ ]
- Reeds and sedges [X]
- Shrubs [X]
- Saplings [X]
- Trees [X]

Tree Types
- None [ ]
- Alder [ ]
- Ash [X]
- Beech [ ]
- Birch [ ]
- Cottonwood [X]
- Elm [ ]
- Sweet gum [ ]
- Willow [X]
- Sycamore x

Density
- None [ ]
- Sparce [ ]
- Medium [ ]
- Dense [X]

Spacing
- Continuous [ ]
- Close [X]
- Wide [ ]

Location
- Whole bank [X]
- Bank top [ ]
- Mid-bank [ ]
- Bank toe [ ]

Diversity
- Mono-stand [ ]
- Mixed [X]
- Climax-vegetation [ ]

Health
- Healthy [X]
- Fair [ ]
- Poor [ ]
- Dead [ ]

Age
- Imature [X]
- Mature [X]
- Old [ ]

Height
- Short [ ]
- Medium [X]
- Tall [X]

Extent
- Wide [X]
- Medium [ ]
- Narrow [ ]

PART 15: RIGHT BANK EROSION PROCESSES

Status
- Intact [X]
- Eroding [ ]
- Advancing [ ]

Severity
- Insignificant [ ]
- Mild [ ]
- Significant [ ]
- Serious [ ]
- Catastrophic [ ]

Extent
- Toe [ ]
- Lower bank [ ]
- Upper bank [ ]
- Whole bank [ ]

Estimated rate
- < 3ft/yr [ ]
- 3 - 10 ft/yr [ ]
- 10 - 25 ft/yr [ ]
- >25 ft/yr [ ]

Location
- General [ ]
- Outside Meander [ ]
- Inside Meander [ ]
- Opposite a bar [ ]
- Behind a bar [X]
- Opposite a structure [ ]
- Adjacent to structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]
- Other [ ]

Processes
- Flow entrainment [ ]
- Piping [ ]
- Freeze/thaw [ ]
- Sheet erosion [ ]
- Rilling + gullying [ ]
- Wind waves [ ]
- Vessel Forces [ ]
- Ice rafting [ ]
- Aeolian [ ]
- Other [ ]

Distribution of Each Process on Bank

	Process 1	Process 2	Process 3	Process 4
Toe	[ ]	[ ]	[ ]	[ ]
Lower bank	[ ]	[ ]	[ ]	[ ]
Upper bank	[ ]	[ ]	[ ]	[ ]
Whole bank	[ ]	[ ]	[ ]	[ ]

PART 16: RIGHT BANK FAILURE MECHANICS

Status
- Stable [X]
- Unreliable [ ]
- Unstable [ ]

Severity
- Insignificant [ ]
- Moderate [ ]
- Serious [ ]

Extent
- Toe [ ]
- Lower bank [ ]
- Upper bank [ ]
- Whole bank [ ]

Frequency
- None [ ]
- Occasional [ ]
- Frequent [ ]

Location
- General [ ]
- Outside Meander [ ]
- Inside Meander [ ]
- Opposite a bar [ ]
- Behind a bar [X]
- Opposite structure [ ]
- Adjacent structure [ ]
- Dnstream of structure [ ]
- Upstream of structure [ ]

Failure Mode
- Shallow slide [ ]
- Rotational slip [ ]
- Slab-type [ ]
- Pop-out failure [ ]
- Cantilever failure [ ]
- Piping [ ]
- Flow failure [ ]
- Ravelling [ ]

Distribution of Each Mode on Bank

	Mode 1	Mode 2	Mode 3	Mode 4
Toe	[ ]	[ ]	[ ]	[ ]
Lower bank	[ ]	[ ]	[ ]	[ ]
Upper bank	[ ]	[ ]	[ ]	[ ]
Whole bank	[ ]	[ ]	[ ]	[ ]

PART 17: RIGHT BANK BERM CHARACTERISTICS

Present Status
- No berm [X]
- small berm [ ]
- medium berm [ ]
- large berm [ ]

Berm Location
- None [ ]
- Only inside bends [ ]
- Continuous [ ]

Berm Material Size Data
- D50 (mm) [ ]
- sorting coefficient [ ]

Berm Materials
- Silt/clay [ ]
- Sand/silt/clay [ ]
- Sand/silt [ ]
- Sand [ ]
- Sand/gravel [ ]
- Gravel [ ]
- Gravel/cobbles [ ]
- Cobbles [ ]
- Cobbles/boulders [ ]
- Boulders [ ]
- Bed rock [ ]

Berm Vegetation
- None [ ]
- Cleared [ ]
- Grass and flora [ ]
- Reeds and sedges [ ]
- Shrubs [ ]
- Saplings [ ]
- Trees [ ]

Age
- Imature [ ]
- Mature [ ]
- Old [ ]

Berm Tree Types
- None [ ]
- Alder [ ]
- Ash [ ]
- Birch [ ]
- Cottonwood [ ]
- Elm [ ]
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- Sweet gum [ ]
- Willow [ ]
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Density
- None [ ]
- Sparce [ ]
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Diversity
- Mono-stand [ ]
- Mixed [ ]
- Climax-vegetation [ ]

Spacing
- Continuous [ ]
- Close [ ]
- Wide [ ]

Health
- Healthy [ ]
- Unhealthy [ ]
- Dead [ ]

Height
- Short [ ]
- Medium [ ]
- Tall [ ]

Roots
- Normal [ ]
- Advantitious [ ]
- Exposed [ ]

APPENDIX D Comments from Corps' Engineers on Sheets and Guidelines

1. FIELD DATA COLLECTION AND EQUIPMENT

- Add Dictaphone for making field notes.
- surveying, use a transit for more accurate work.
- Supply a disposable camera for field photographs.
- Maintain groups of 3 people for work.
- Replace hammer/hatchet with a machete.
- Use a Brunton Compass instead of separate compass and inclinometer.
- Add a set of webbing for holding equipment.
- Add a canteen.
- Add an umbrella.
- Add a hip chain.
- Supply a longer leveling rod. 25ft in place of 14ft.
- Include a sediment sizer and centimeter scale.

2. SEDIMENT ASSESSMENT SHEETS AND GUIDELINES

- Add place for notes from local people.
- Add a place for field sketches.
- Mark on sheets + maps places for adding likely spots for HEC-6 x-sections.
- No need to differentiate bank erosion processes from failure mechanisms.
- Locate features on maps and aerial photographs.
- In Part 5, add a place for recording presence of clay plugs.
- Make sheets laminated in plastic and use a grease pencil to fill them in.
- Add overbank values for Manning's "n" coefficients.
- Use photographs to illustrate user manual, like Ven Te Chow's book.
- Explain what is meant by a large berm.
- Put in places to take photographs.
- Add section on debris in channel and on flood plain.
- Armoring section, add size of largest particle moved.
- Add Appendix on sediment properties and Wentworth Scale.
- Turn the sheets into computer input sheets for data storage and retrieval.

3. INTERPRETATION OF SEDIMENT ASSESSMENT SHEET INFORMATION.

A. Groups 1,2 and 3.

- Stream is graded with respect to aggradation and degradation. It has degraded in the past, but is no longer doing so. In fact it shows some evidence of aggradation in terms of bed, bar and overbank sedimentation.

- Stream width is generally stable, but with some narrowing at specific locations. Point bars in bends appear to be growing and advancing into channel and above bridges narrowing is evident. Generally, though width is adjusted.

- The bed of the channel is stable through the study reach with no clear scouring or filling.

- The channel is moving laterally as expected for a sinuous stream. The right bank is stable but the left bank shows places of instability and failure at the outside of bends. Migration is mostly towards the left bank therefore.

- Problems related to sediment impacts are not serious. Both bridges appear to be in no danger of failure due to scouring, filling or bank erosion. Houses built in the flood plain on the left bank are sufficiently far back from the channel. It is concluded that no economic justification for engineering action exists at present. However, the level of sedimentary activity warrants continued monitoring of the reach.

- One possible cause of future problems concerns an abandoned channel on the right side of the present stream course. This is deeply incised and not very secure. As the channel cuts across the inside of a large bend, it has the potential to capture the flow through a channel avulsion. This would occur if overbank flow in the presently abandoned channel head-cut sufficiently to capture the flow during flood recession. Worst case scenario is a re-creation of an old channel alignment putting the lower (Tiftontown) bridge in jeopardy. At present the flood plain and abandoned channel are heavily vegetated with trees, giving a very high friction factor and ensuring slow overbank flow velocities. These tress should be left to serve this purpose. If they were to be removed, a grade control structure and riprap should be installed to prevent possible head cutting and channel avulsion.

B. Groups 3,4 and 5.

- Channel is degradational, recovering to close to graded. Some bed armoring is apparent, indicating past degradational tendencies in the channel.

- Width is fairly stable, but with some narrowing through berm building.

- Bars are not extensive or dominant. They are moving through cutting and filling.

- Banks are cutting at the outside of bends and filling at the inside of bends.

- Some local engineering protection of the banks may be called for at the outer bank in the active meander bend, in sub-reach 2.

- A short analysis of planform changes historically helps explain trends in channel sediment related problems. In 1956 the sinuosity of the channel was approximately 1.7, according to the aerial photographs supplied. In the early 1960's the channel was straightened upstream of Tiftontown bridge, reducing the sinuosity to 1.4. Since then bed scouring and accelerated bank erosion at the outside of bendways has occurred, leading to a recovery of sinuosity to about 1.65. As this is close to the original value, it may be concluded that a reduction in lateral activity should be expected. A regime analysis should be performed to determine what the regime geometry of this channel is and see where the present channel sets in relation to the regime condition.